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Roberts et al.

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(54) **VARIABLE GEOMETRY TURBINE**

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F01D 17/16 (2006.01)
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USPC 415/150, 157, 158; 60/602; 29/889.21, 29/525.01, 525.13
See application file for complete search history.

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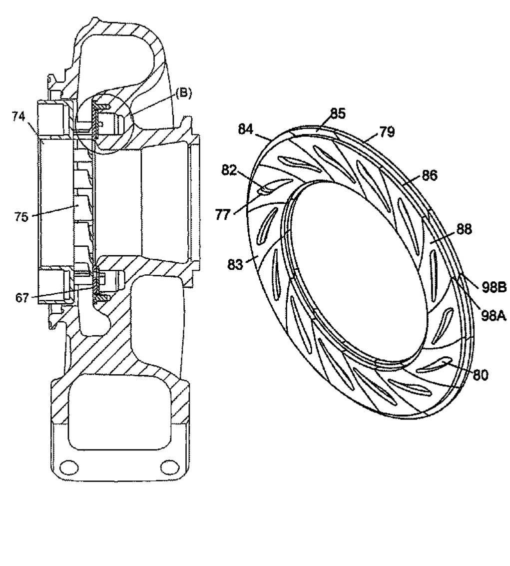
(57) **ABSTRACT**

A variable geometry turbine comprises: a turbine wheel in a housing for rotation about a turbine axis; an annular inlet passage defined between respective radial inlet surfaces of first and second wall members, at least one of said first and second wall members being moveable along the turbine axis to vary the size of the inlet passage; an array of vanes extending across the inlet passage, said vanes being connected to said first wall member; a complementary array of vane slots defined by the second wall member, said vane slots configured to receive said vanes to accommodate relative movement between the first and second wall members; the second wall member comprising at least two axially adjacent co-axial plates, a first plate defining a first array of openings which overlie a second array of openings defined by a second plate so as to define said array of vane slots, said first plate being fixed to said second plate.

9 Claims, 24 Drawing Sheets



(51) **Int. Cl.**
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F02B 37/24 (2006.01)
F02C 6/12 (2006.01)

(52) **U.S. Cl.**
CPC ***F02B 37/24*** (2013.01); ***F02C 6/12*** (2013.01); *F05D 2220/40* (2013.01); *Y02T 10/144* (2013.01); *Y10T 29/49321* (2015.01)

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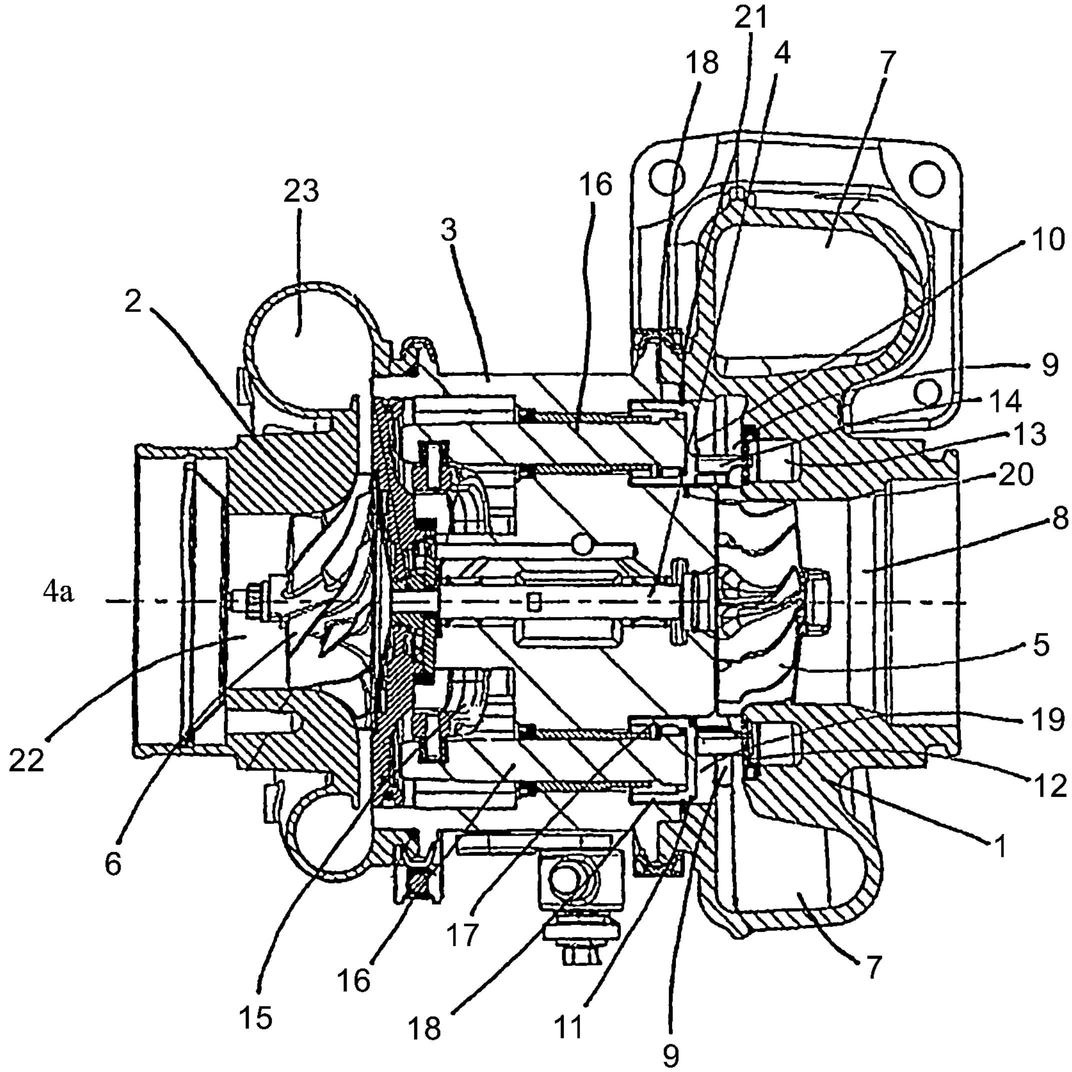

Fig. 1

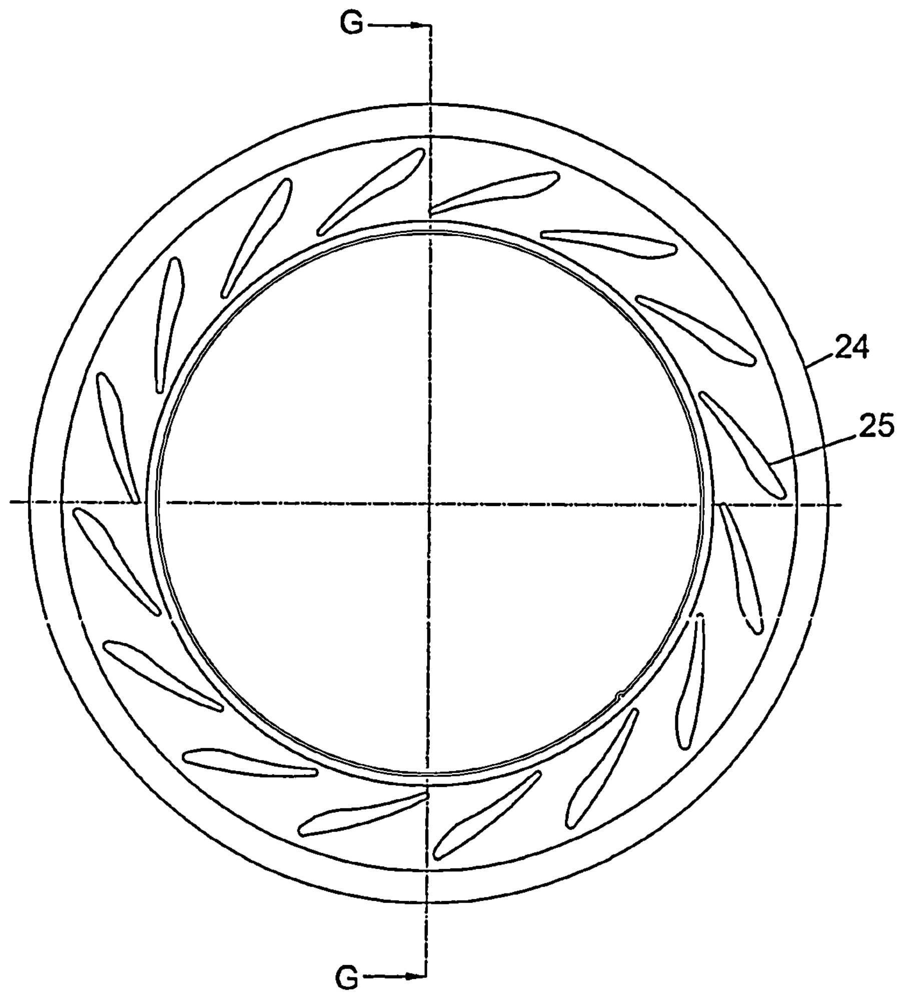

Fig.2A
(Prior Art)

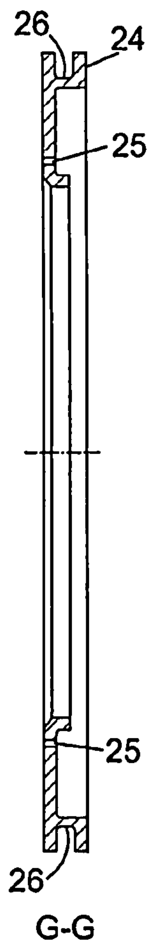

Fig.2B
(Prior Art)

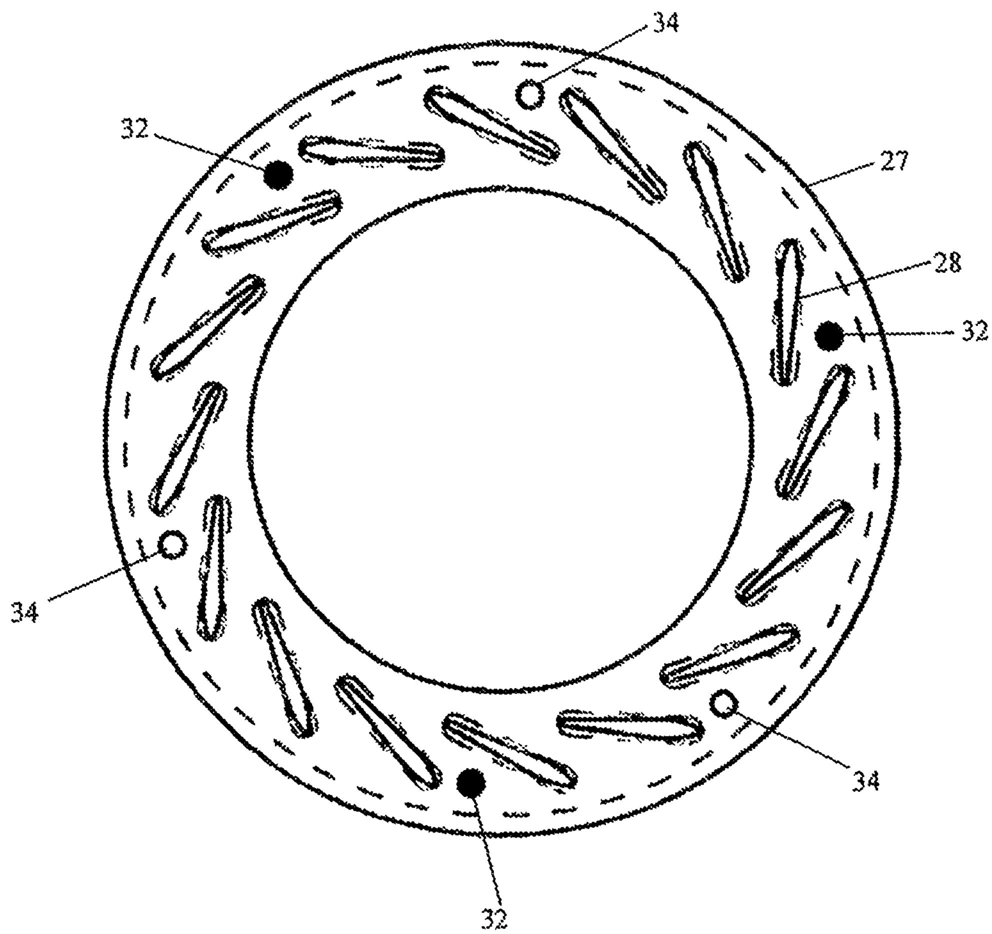

Fig. 3A

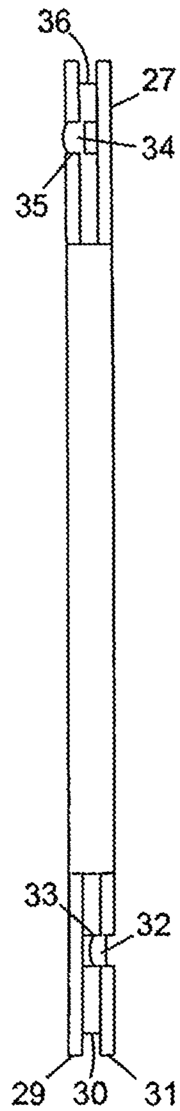

Fig. 3B

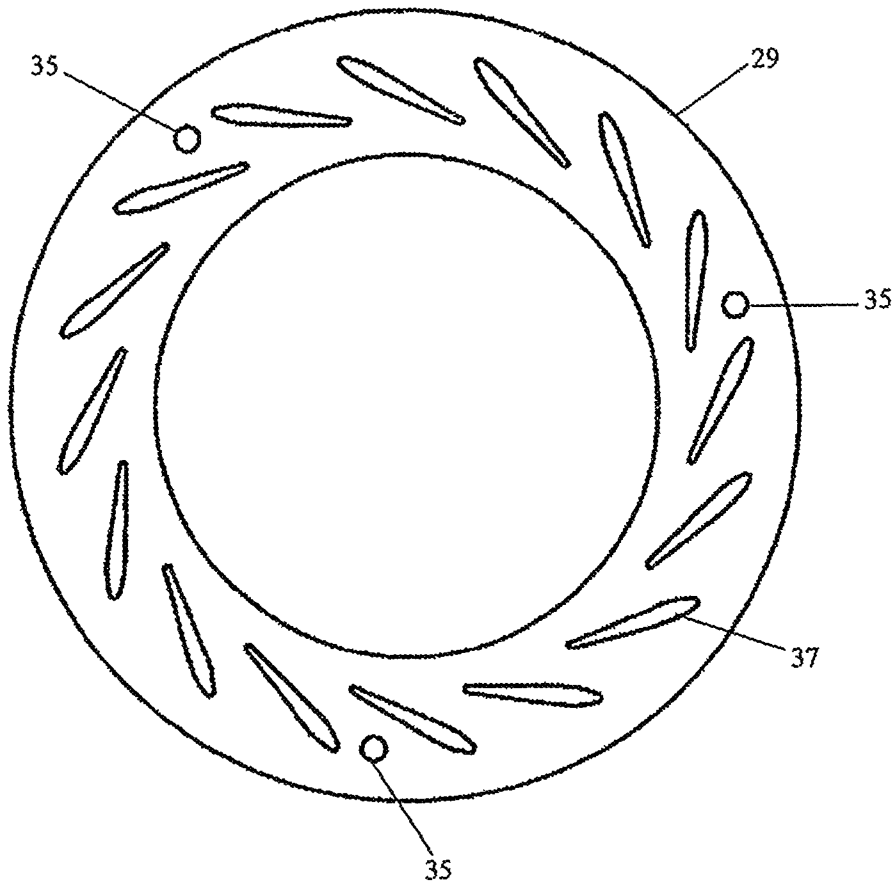

Fig. 4A

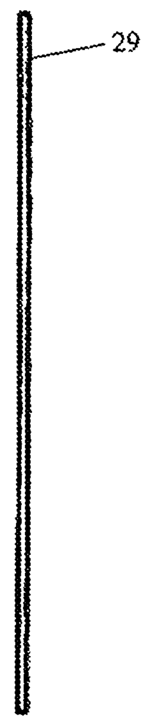

Fig. 4B

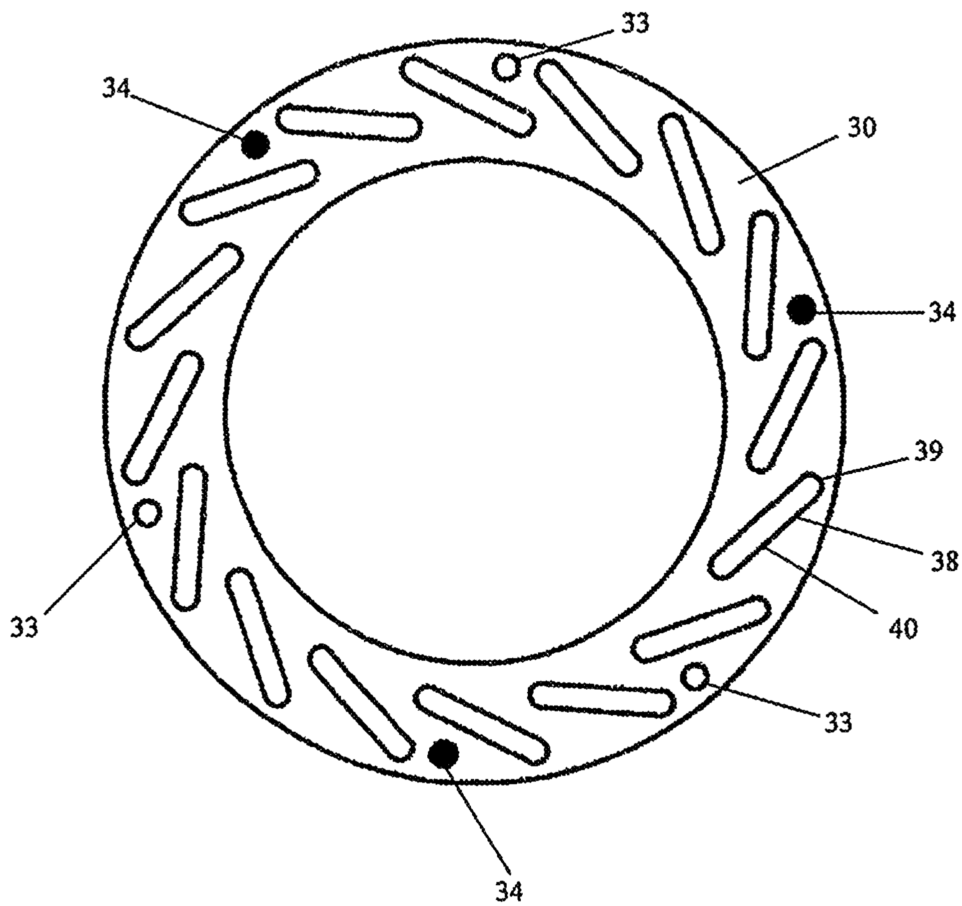

Fig. 5A

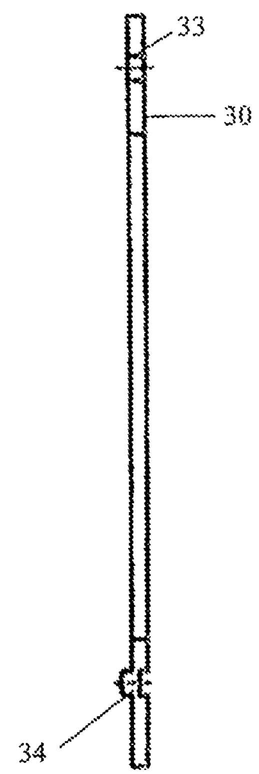

Fig. 5B

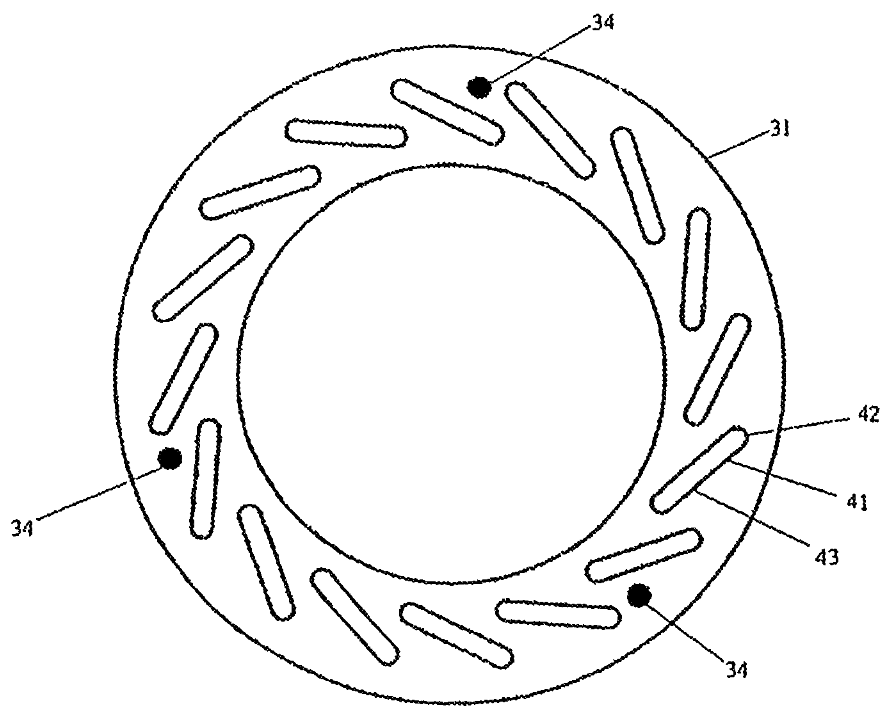

Fig. 6A

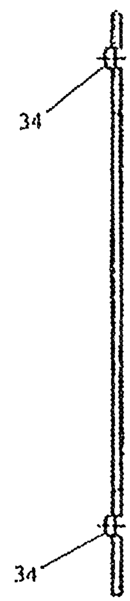

Fig. 6B

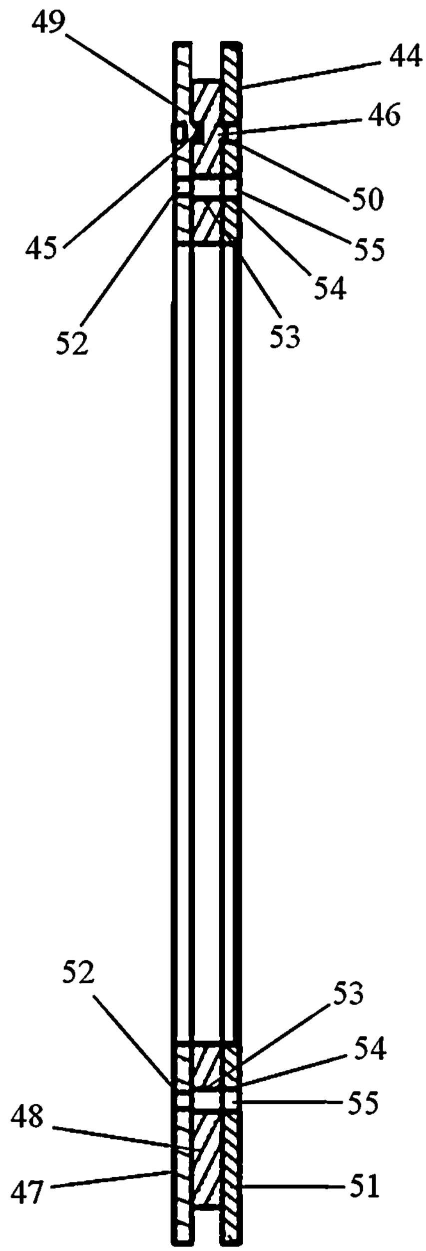

Fig. 7

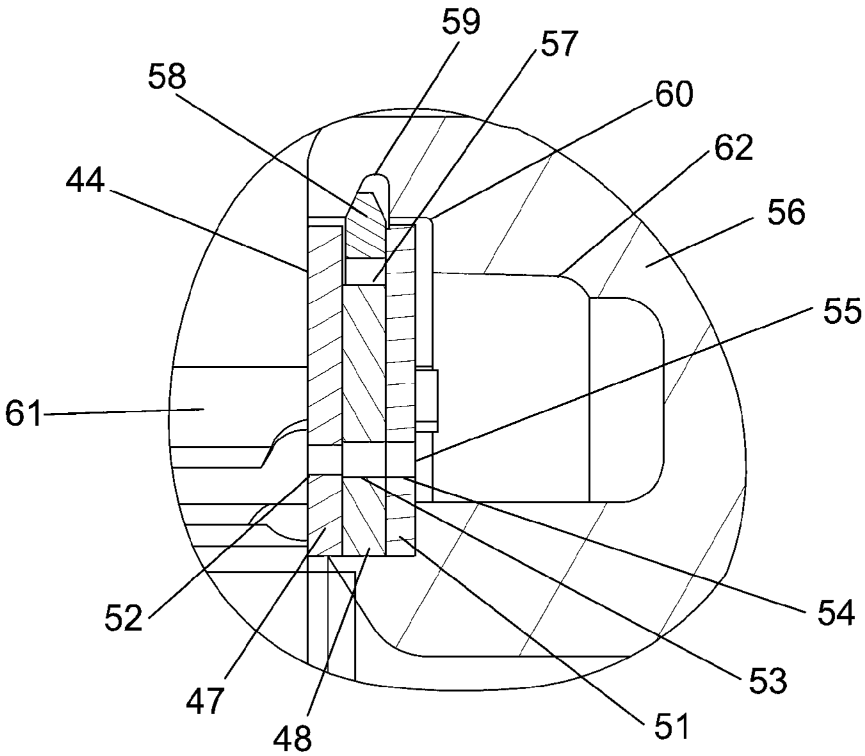
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Fig.8A

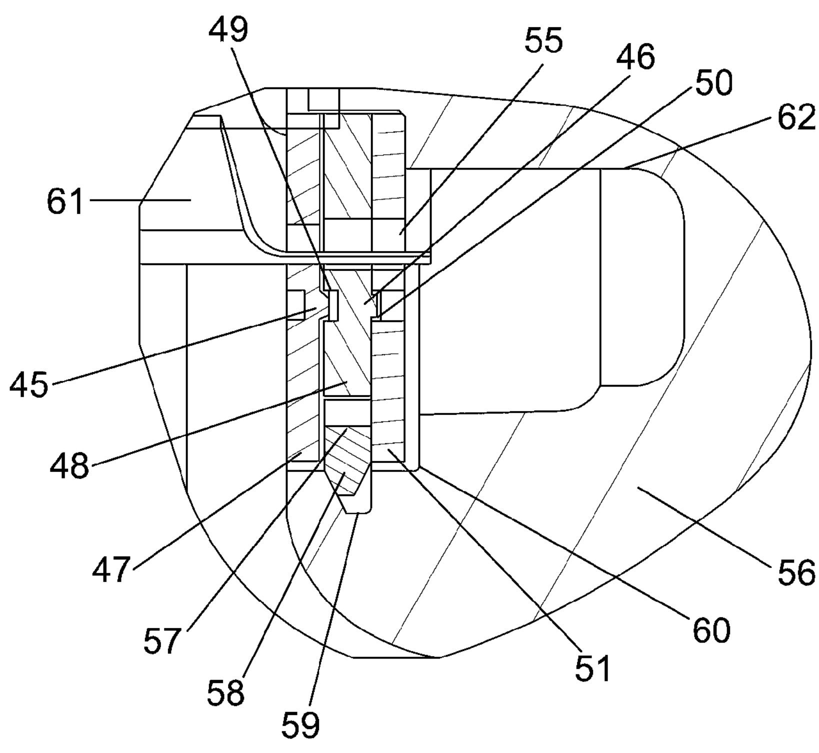
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Fig.8B

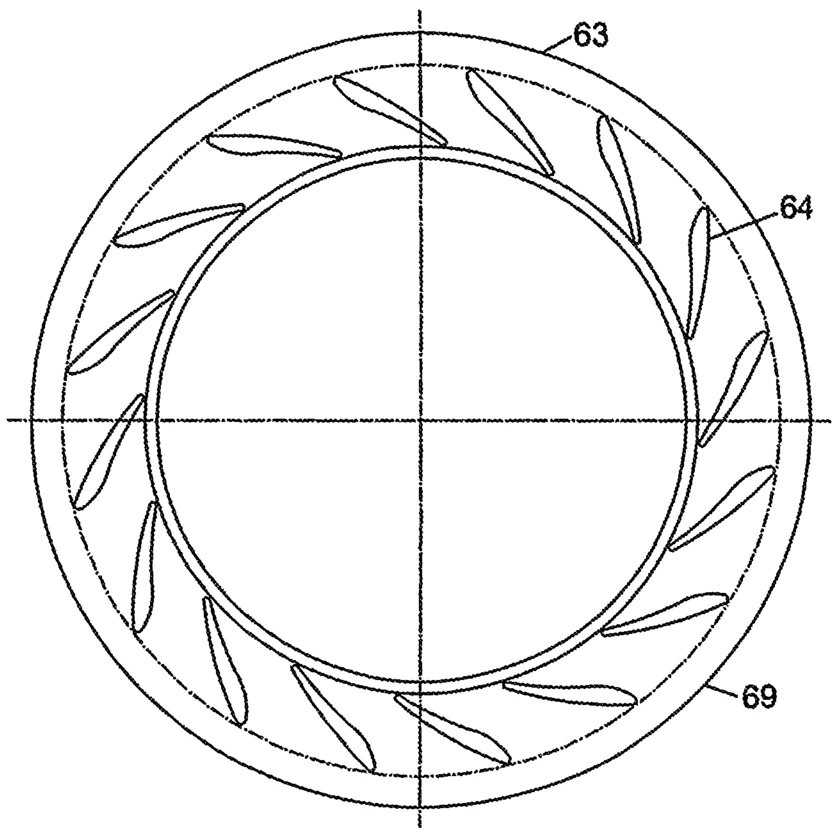

Fig. 9

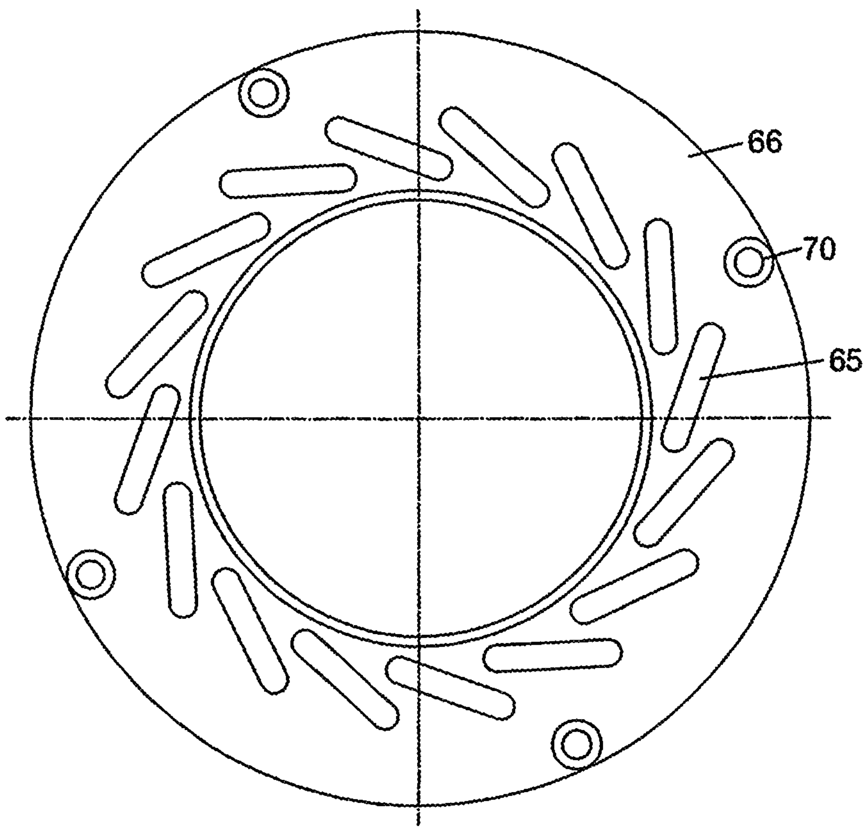

Fig. 10

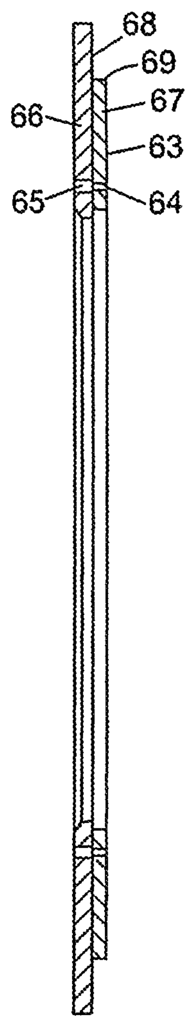

Fig. 11

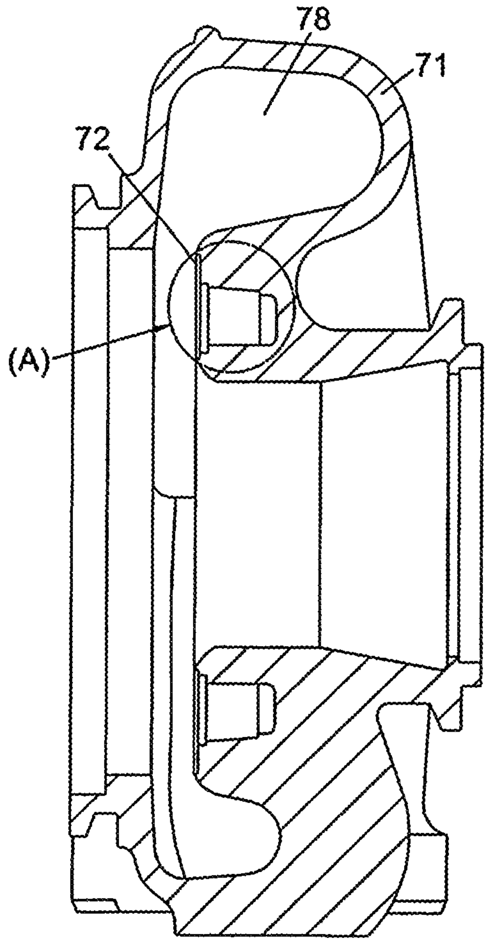

Fig. 12A

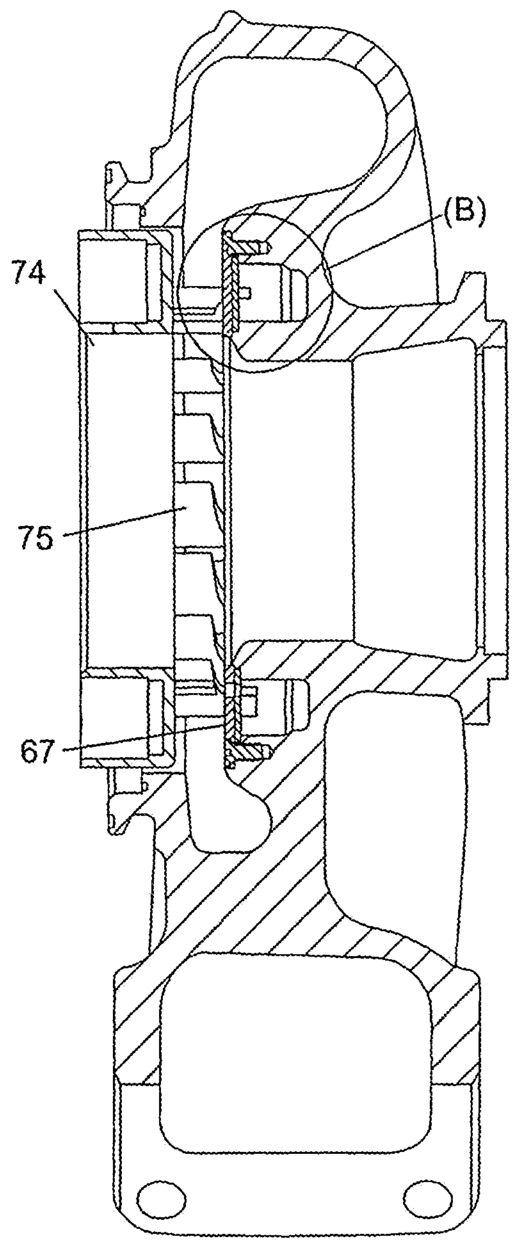

Fig. 12B

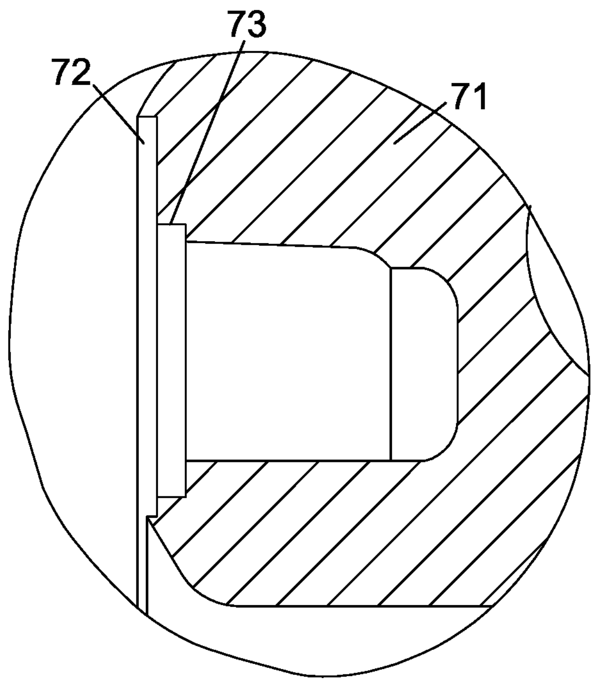

Fig.13A

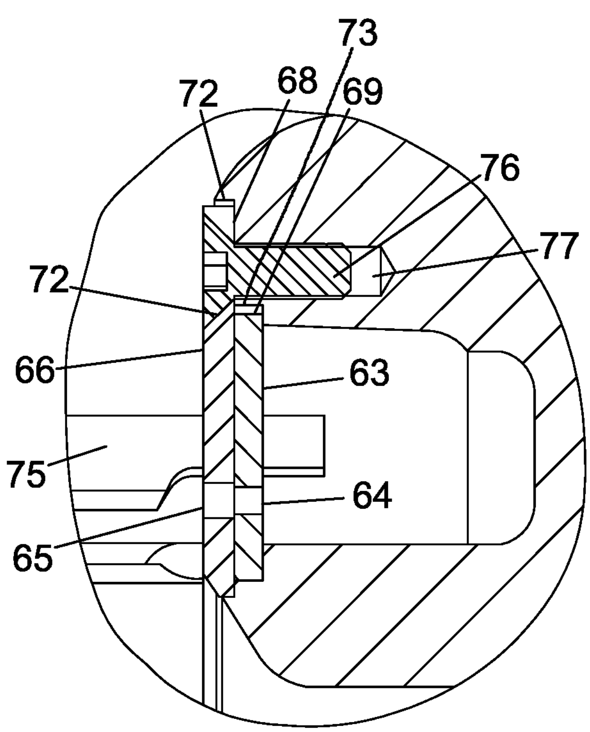

Fig.13B

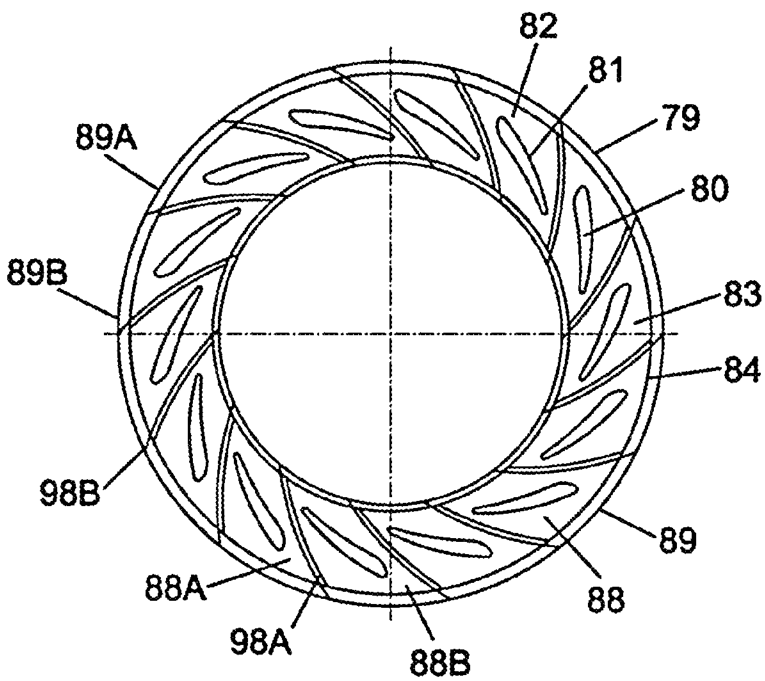

Fig. 14A

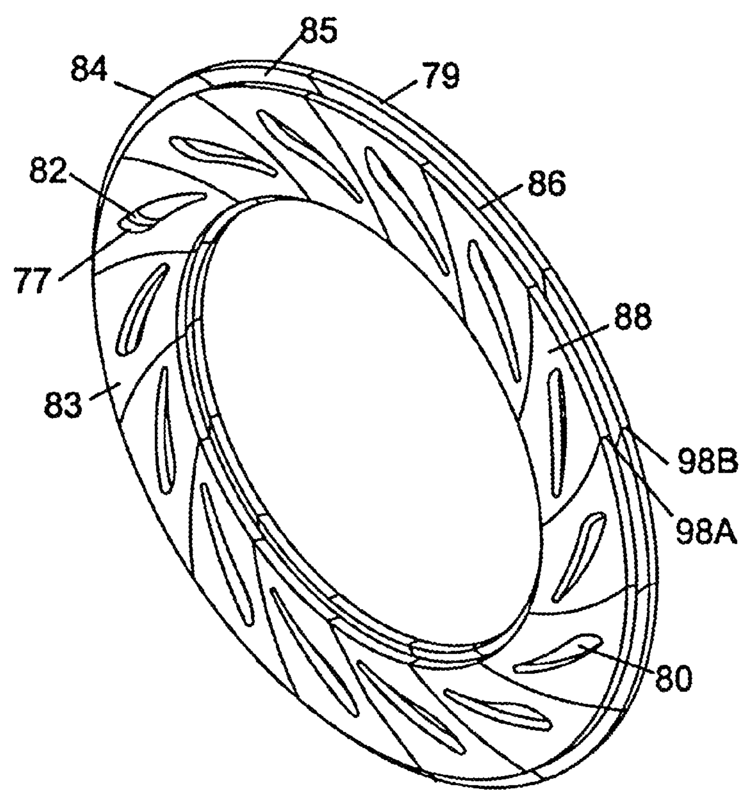

Fig. 14B

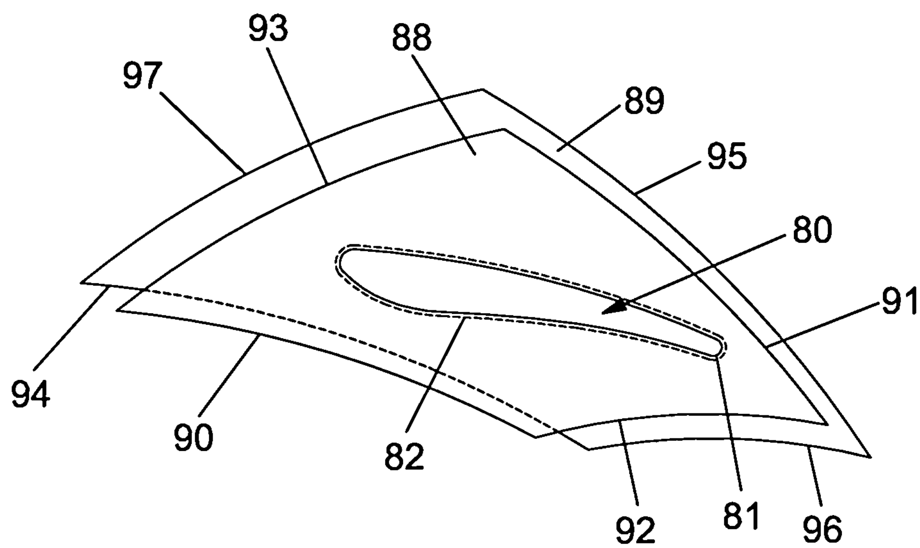

Fig.15

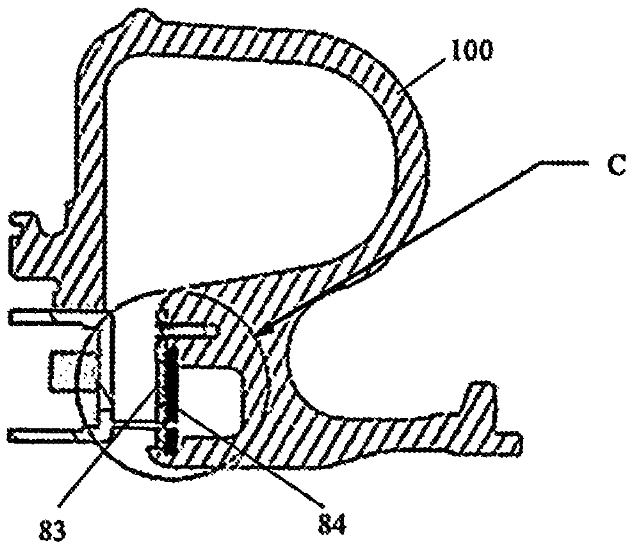

Fig. 16A

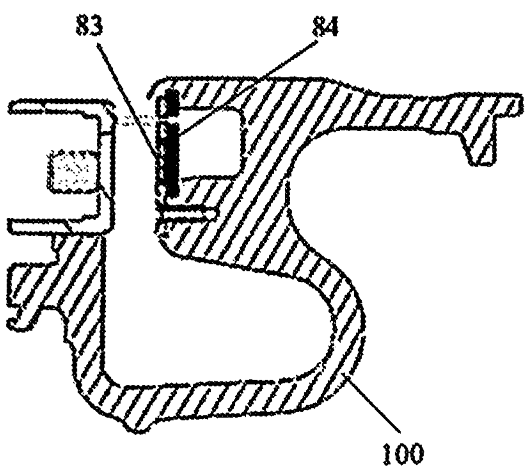

Fig. 16B

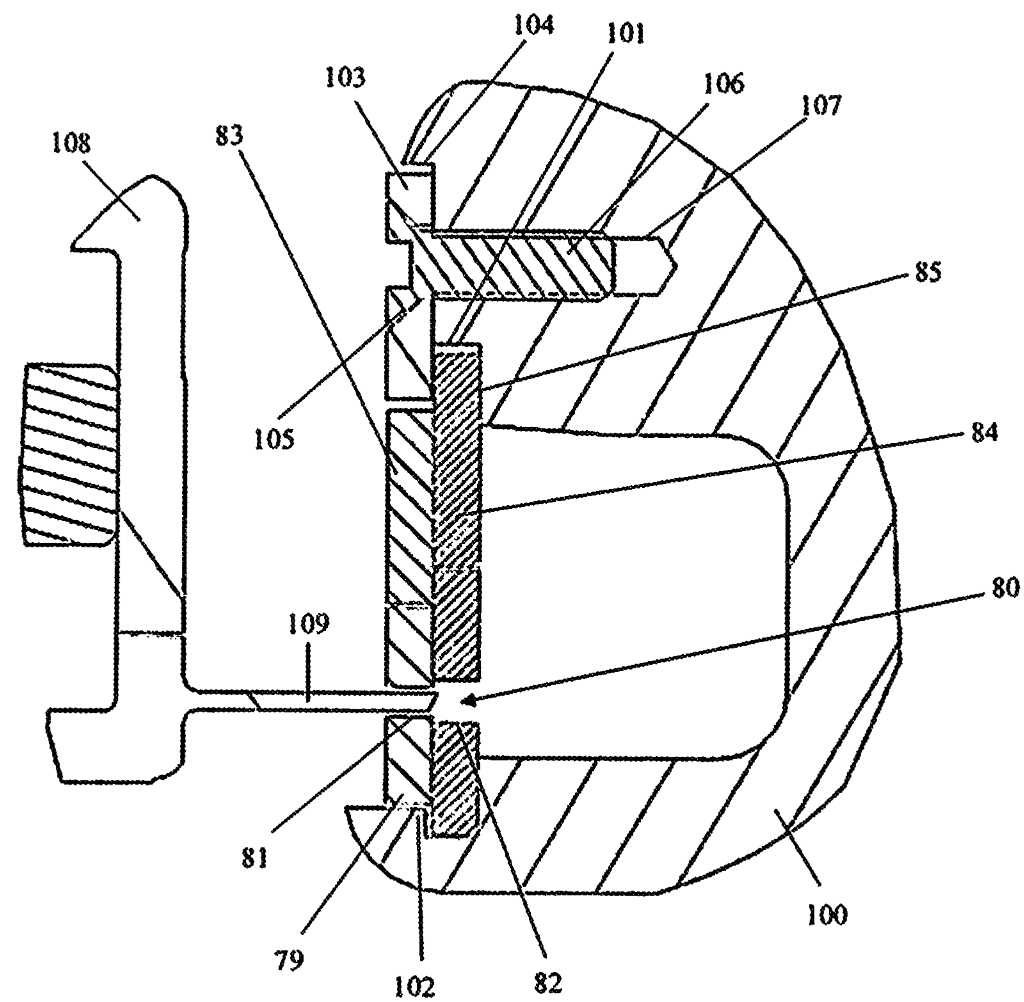

Fig. 17

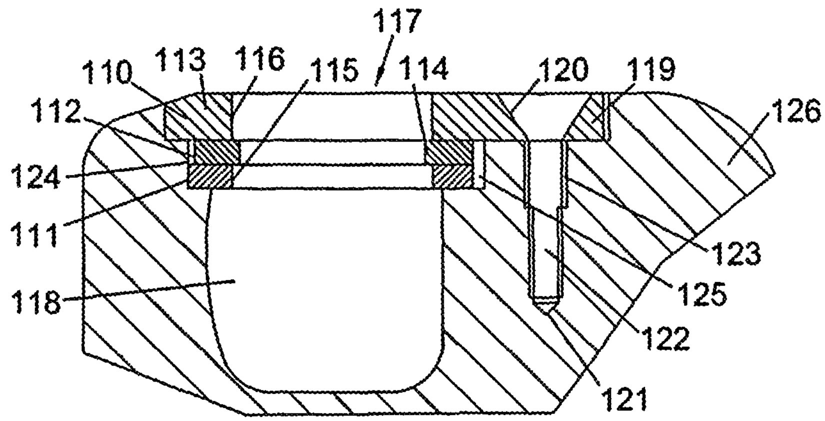

Fig. 18A

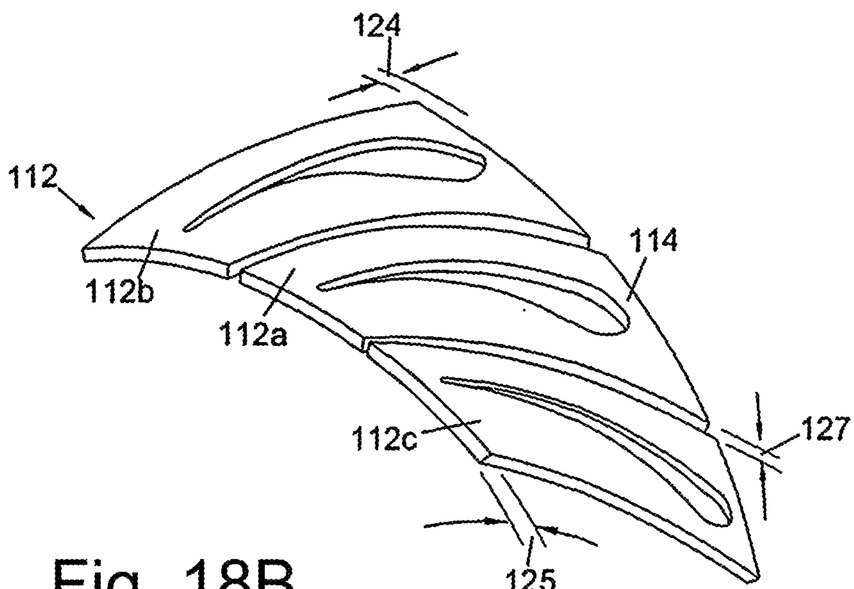

Fig. 18B

VARIABLE GEOMETRY TURBINE

The present invention relates to a variable geometry turbine. Particularly, but not exclusively, the present invention relates to variable geometry turbochargers.

A conventional turbine essentially comprises an exhaust gas driven turbine wheel mounted on a rotatable shaft within a turbine housing connected downstream of an engine outlet manifold. Rotation of the turbine wheel drives either a compressor wheel mounted on the other end of the shaft within a compressor housing to deliver compressed air to an engine intake manifold, or a gear which transmits mechanical power to an engine flywheel or crankshaft. The turbine shaft is conventionally supported by journal and thrust bearings, including appropriate lubricating systems, located within a bearing housing.

Turbochargers are well known devices for supplying air to the intake of an internal combustion engine at pressures above atmospheric pressure (boost pressures). In turbochargers, the turbine stage comprises a turbine chamber within which the turbine wheel is mounted; an annular inlet passageway defined between opposite radial walls arranged around the turbine chamber; an inlet arranged around the inlet passageway; and an outlet passageway extending from the turbine chamber. The passageways and chambers communicate such that pressurised exhaust gas admitted to the inlet chamber flows through the inlet passageway to the outlet passageway via the turbine and rotates the turbine wheel. Turbine performance can be improved by providing vanes, referred to as nozzle vanes, in the inlet passageway so as to deflect gas flowing through the inlet passageway towards the direction of rotation of the turbine wheel.

Turbines may be of a fixed or variable geometry type. Variable geometry turbines differ from fixed geometry turbines in that the size of the inlet passageway can be varied to optimise gas flow velocities over a range of mass flow rates so that the power output of the turbine can be varied to suite varying engine demands. For instance, when the volume of exhaust gas being delivered to the turbine is relatively low, the velocity of the gas reaching the turbine wheel is maintained at a level which ensures efficient turbine operation by reducing the size of the annular inlet passageway. Turbochargers provided with a variable geometry turbine are referred to as variable geometry turbochargers.

In one known type of variable geometry turbine, an axially moveable wall member, generally referred to as a “nozzle ring”, defines one wall of the inlet passageway. The position of the nozzle ring relative to a facing wall of the inlet passageway is adjustable to control the axial width of the inlet passageway. Thus, for example, as gas flows through the turbine decreases, the inlet passageway width may be decreased to maintain gas velocity and optimise turbine output. This arrangement differs from another type of variable geometry turbine in which a variable guide vane array comprises adjustable swing guide vanes arranged to pivot so as to open and close the inlet passageway.

The nozzle ring may be provided with vanes which extend into the inlet and through vane slots provided in a “shroud” defining the facing wall of the inlet passageway to accommodate movement of the nozzle ring. Alternatively vanes may extend from the fixed facing wall and through vane slots provided in the nozzle ring.

Typically the nozzle ring may comprise a radially extending wall (defining one wall of the inlet passageway) and radially inner and outer axially extending walls or flanges which extend into an annular cavity behind the radial face of the nozzle ring. The cavity is formed in a part of the turbocharger housing (usually either the turbine housing or the turbocharger bearing housing) and accommodates axial movement of the nozzle ring. The flanges may be sealed with respect to the cavity walls to reduce or prevent leakage flow around the back of the nozzle ring.

In one common arrangement of a variable geometry turbine the nozzle ring is supported on rods extending parallel to the axis of rotation of the turbine wheel and is moved by an actuator which axially displaces the rods. Nozzle ring actuators can take a variety of forms, including pneumatic, hydraulic and electric and can be linked to the nozzle ring in a variety of ways. The actuator will generally adjust the position of the nozzle ring under the control of an engine control unit (ECU) in order to modify the airflow through the turbine to meet performance requirements.

As mentioned above, as the nozzle ring is moved to adjust the axial width of the inlet passageway, the guide vanes may extend into accurately defined vane slots in a shroud plate to accommodate the movement. Typically, shroud plates are made by turning from bar, where each plate is essentially a disc of material, often provided with a circumferential groove extending around the periphery of the disc to accommodate a locating ring which retains the disc within the turbine housing. After turning, the vane slots are usually produced in the disc, one at a time, by numerical control (NC) laser cutting. In order to ensure efficient functioning of the nozzle ring and shroud plate assembly it is important that the size, shape and position of the vane slots accurately matches that of the guide vanes. This introduces very fine tolerances to the manufacture of both the shroud plate and the nozzle ring carrying the guide vanes. Production of shroud plates and nozzle rings is therefore an undesirably complicated and costly process requiring very careful control of a number of different manufacturing processes to ensure the two components function together satisfactorily.

It is an object of the present invention to obviate or mitigate one or more of the problems set out above.

According to a first aspect of the present invention there is provided variable geometry turbine comprising:

- a turbine wheel supported in a housing for rotation about a turbine axis;
- an annular inlet passage defined between respective radial inlet surfaces of first and second wall members, at least one of said first and second wall members being moveable along the turbine axis to vary the size of the inlet passage;
- an array of vanes extending across the inlet passage, said vanes being connected to said first wall member;
- a complementary array of vane slots defined by the second wall member, said vane slots being configured to receive said vanes to accommodate relative movement between the first and second wall members;
- wherein the second wall member comprises at least two axially adjacent co-axial plates, a first of said plates defining a first array of openings which overlie a second array of openings defined by a second of said plates so as to define said array of vane slots, said first plate being fixed to said second plate.

Forming the second wall member from at least two axially adjacent co-axial plates is advantageous since it can simplify the process of producing the wall member with the appropriate dimensions and arrangement of vanes slots to suit a particular application. Preferably the co-axial plates are concentrically arranged with respect to one another. Moreover, the plates are preferably annular in shape.

In a preferred embodiment the cross-sectional shape transverse to said turbine axis of at least one of the openings in said first array of openings more closely matches the cross-sectional shape transverse to said turbine axis of the vane that said at least one opening is arranged to receive than the cross-sectional shape transverse to said turbine axis of at least one of the openings in said second array of openings. Providing at least one of the openings in the second plate with a cross-sectional shape which less closely matches the cross-sectional shape of the vane which it is intended to receive, enables cheaper and simpler manufacturing processes to be used in the manufacture of the second plate. For example, while the cross-sectional shape of the openings in the first plate is preferably very similar to the cross-sectional shape of the vane which the opening was intended to receive, the underlying opening in the second plate may have a relatively simple cross-sectional shape such as a round, square, rectangular or oval shape provided the opening in the second plate is sufficiently large to encompass the overlying opening in the first plate. Thus it is preferred that said at least one opening in said first array of openings may axially overlie said at least one opening in said second array of openings to define one slot of said array of vanes slots.

In a preferred example, the openings in the second plate have a substantially rectangular cross-sectional shape but with the short edges of the rectangle being curved for ease of manufacture.

In a further preferred embodiment said first plate may be substantially rotationally and/or radially fixed relative to said second plate. Preferably the first plate is substantially fixed both rotationally and radially relative to the second plate. The first and second plates may be laminated together. Moreover, the first and second plates may be fixed together by an adhesive, braze, rivet, screw, weld or the like.

One of said first and second plates may define at least one axially extending projection, such as a semi-shear or locating pin, configured for receipt in a complementary recess defined by the other of the first and second plates.

The first and second plates may be positioned axially relative to the first wall member to suit a particular application. For certain applications it may be preferable for the first plate may be positioned axially closer to said first wall member than said second plate, or for said second plate to be positioned axially closer to said first wall member than said first plate.

The second wall member may comprise any number of additional co-axial or concentric plates. Thus, the second wall member may comprise at least a third co-axial or concentric plate that is axially adjacent to said second plate, said third plate defining a third array of openings which overlie the second array of openings defined by the second plate so as to further define said array of vane slots. The third plate may be annular in shape. It is thus preferred that the second plate is interposed between the first and third plates.

In order to further simplify and reduce the cost of manufacturing the third (and any subsequent) co-axial or concentric plates, it is preferred that the cross-sectional shape transverse to said turbine axis of at least one of the openings in said first array of openings more closely matches the cross-sectional shape transverse to said turbine axis of the vane that said at least one opening is arranged to receive than the cross-sectional shape transverse to said turbine axis of at least one of the openings in said third array of openings.

The cross-sectional shape of the third array of openings may be the same or may differ from the cross-sectional shape of the second array of openings. Thus, said cross-sectional shape transverse to said turbine axis of at least one of the openings in said third array of openings may substantially match the cross-sectional shape transverse to said turbine axis of at least one of the openings in said second array of openings.

Preferably said at least one opening in said third array of openings axially overlies said at least one opening in said second array of openings to further define one slot of said array of vanes slots.

Preferably the third plate is fixed to the second plate.

The third plate may be laminated to the second plate. Moreover, the third plate may be fixed to the second plate by an adhesive, braze, rivet, screw, weld or the like.

One of said second and third plates may define at least one further axially extending projection (e.g. semi-shear or locating pin) configured for receipt in a complementary recess defined by the other of the second and third plates.

The second wall member may be supported within a turbine housing in any appropriate manner provided the means of fixing the second wall member is appropriate for the particular application.

Said second wall member may define a circumferential groove extending around the radially outermost edge of the second wall member, said groove arranged to receive a locating ring to retain the second wall member within the turbine housing. This may be achieved by the first and third plates possessing larger respective diameters than the second plate, such that the difference in the diameters of the three plates at least partly defines said circumferential groove.

Rather than using a locating ring the second wall member may be connected to a turbine housing using some form of fastener such as a bolt, rivet or the like. In this case, it may be advantageous to form at least one of the plates making up the second wall member so as to define a larger outer diameter than one or more of the other plates making up the second wall member such that one or more fasteners can be inserted through the radially extended portion of the larger plate and into the turbine housing thereby fixing the second wall member to the housing.

In a second aspect of the present invention there is provided a variable geometry turbine comprising:

- a turbine wheel supported in a housing for rotation about a turbine axis;
- an annular inlet passage defined between respective radial inlet surfaces of first and second wall members, at least one of said first and second wall members being moveable along the turbine axis to vary the size of the inlet passage;
- an array of vanes extending across the inlet passage, said vanes being connected to said first wall member;
- a complementary array of vane slots defined by the second wall member, said vane slots being configured to receive said vanes to accommodate relative movement between the first and second wall members;

wherein the second wall member comprises at least two axially adjacent co-axial plates, a first of said plates defining a first array of openings which overlie a second array of openings defined by a second of said plates so as to define said array of vane slots, and further wherein said first plate is rotationally and/or radially moveable relative to said second plate.

In this way, the precise positioning of the first array of openings relative to the second array of openings can be adjusted, which will thereby adjust the location of the vanes slots defined by the overlapping regions of the first and second arrays of openings. This allows the arrangement of vane slots in the second wall member to be optimised for a particular array of vanes connected to the first wall member. This is advantageous since it allows the array of vanes to be manufactured to a wider tolerance thereby reducing the cost and complexity of manufacturing the first wall member and array of vanes.

In a preferred embodiment the second plate is positioned axially closer to the first wall member than the first plate. This results in the second plate facing into the inlet passage of the turbine. Thus, in embodiments in which the cross-sectional shape of the openings in the first array of openings more closely matches that of the vanes than the second array of openings, it is the second array of openings which is exposed to gases flowing through the inlet passage of the turbine rather than the first array of openings. In certain embodiments this will result in openings in the second plate of larger cross-sectional area facing into the inlet passageway and the openings in the first plate of smaller cross-sectional area facing in the opposite direction towards the wall of the turbine housing to which the first wall member is connected.

It is preferred that said second plate is substantially rotationally and/or radially fixed relative to said turbine housing. It is particularly preferred that the second plate is substantially fixed both rotationally and radially to the turbine housing, for example using a suitable type of fastener such as a bolt, rivet or the like.

In one embodiment the second plate may have a larger diameter than the first plate such that a region of the second plate extends radially beyond the circumferential edge of the first plate, said region of the second plate cooperating with one or more fasteners to fasten said second plate to the turbine housing. Any desirable number of fasteners of any suitable type could be used but it is envisaged that it may be advantageous to use at least three or four bolts received in apertures defined by the region of the second plate which extends radially beyond the circumferential edge of the first plate.

It will be appreciated that it is important to ensure that the first and second plates can move relative to one another without causing undesirable levels of wear to either plate. Moreover, undesirably high levels of friction between the plates may damage them making them susceptible to failure and/or corrosion. Thus, a surface of at least one of the first and second plates which faces the other of the first and second plates may be provided with an anti-wear, anti-friction and/or anti-corrosion coating.

In the second aspect of the invention where the first plate is rotationally and/or radially moveable relative to the second plate, this may only be possible during initial optimisation of the second wall member for use with a particular first wall member and array of vanes. By way of example, a braze could be applied between the first and second plates and the vanes inserted into their corresponding vane slots at a sufficiently high temperature such that the braze remain sufficiently fluid to permit relative rotational and/or radial movement between the plates. Once the optimum relative position of the first plate relative to the second plate has been determined for that particular array of vanes, the temperature of the second wall member could then be decreased such that the braze solidifies and thereby fixed the first and second plates together such that rotational and/or radial movement is no longer possible. Alternatively, the first and second plates may be arranged so as to permit free rotational and/or radial movement throughout the lifetime of use of the turbine.

In a still further preferred embodiment of the first aspect of the present invention, said first plate may comprise first and second segments defining respective first and second openings from said first array of openings, said first segment being displaceable relative to said second segment within a major plane of the first plate.

In this embodiment the first plate is formed in segments which are displaceable relative to one another so that their optimum displacement relative to a particular nozzle ring can be readily determined. This embodiment therefore affords a further method for optimising the arrangement of vane slots in the second wall member for receipt of vanes from a particular first wall member. As mentioned above, adjustment may be carried out initially prior to use, for example in combination with brazing the first and second plates together, or a suitable anti-wear, anti-frictional, anti-corrosion coating may be provided on one or more of the segments so that they can move freely relative to one another within the major plane of the first plate throughout use of the turbine.

Each of said segments may comprise generally radially extending leading and trailing edges connected by radially inner and outer edges. A clearance may be defined between the leading edge of one segment and the trailing edge of a neighbouring segment. This clearance can then accommodate relative displacements between neighbouring segments.

Said radially inner and outer edges may possess different lengths. Preferably said radially inner edge is shorter than said radially outer edge. Thus, it is preferred that each segment is flared from its radially inner edge to its radially outer edge.

Said leading and trailing edges may be swept forward relative to said radial line. The leading edge may be swept forward to a greater extent than the trailing edge.

At least one of said leading and trailing edges may be curved relative to a radial line passing through said segment and the turbine axis. Moreover at least one of said inner and outer edges of each segment may be curved.

It is thus preferred that each segment of the first plate has a scimitar-like cross-sectional shape as can be seen in the specific embodiments described below in relation to FIGS. **14**A, **14**B and **15**.

Preferably both of said inner and outer edges of each segment are curved, and said inner and outer edges possess a substantially similar curvature.

In a preferred version of the present embodiment, said second plate comprises first and second segments defining respective first and second openings from said second array of openings, said first segment of the second plate being displaceable relative to said second segment of the second plate within a major plane of the second plate.

Said first segment of the first plate may axially overlie said first segment of the second plate. Preferably overlying segments from the first and second plates are connected together such that rotational and/or radial displacement of a segment relative to the segment it overlies is prevented. Any suitable type of connection between overlying segments may be used, such as brazing.

In a similar fashion to the segments of the first plate, each of said segments of the second plate may comprise generally radially extending leading and trailing edges connected by radially inner and outer edges.

Preferably a further clearance is defined between the leading edge of one segment and the trailing edge of a neighbouring segment. Said further clearance can accommodate relative displacement of segments of the second plate. Where overlying segments of the first and second plates are connected together so as to move in unison, it is preferable that the clearances defined between segments of the first plate and segments of the second plate are similar in shape so as to afford a similar degree of relative movement between segments in the first plate and segments in the second plate.

Said first segment of the second plate may be circumferentially offset with respect to said first segment of the first plate such that said clearance defined between segments of the first plate is circumferentially offset with respect to said further clearance defined between segments of the second plate. In this way the clearances defined between segments of the first plate do not axially overlie clearances defined between segments of the second plate so as to avoid presenting a leak path for gases flowing through the turbine inlet passageway.

The major plane of the first plate and/or second plate may be substantially orthogonal to the turbine axis.

It is preferred that said first plate is positioned axially closer to said first wall member than said second plate.

The periphery of the second plate may be received within a radially extending channel defined by the turbine housing. The second plate may possess a larger diameter than the first plate such that a region of the second plate may be located radially outwardly of the first plate, at least part of said region being retained within said channel by a retaining member. Said retaining member may be positioned axially closer to said first wall member than said second plate. Said retaining member may be fastened to the turbine housing. The means of fastening may take any appropriate form, such as bolts, rivets and/or screws. Moreover any desirable number and/or arrangement of fasteners may be employed. By way of example only, it is envisaged that providing the retaining member with four equally angularly spaced apertures to receive suitable fasteners may be suitable.

At least one of the co-axial or concentric plates comprised in the second wall member may be formed from stainless steel.

According to a third aspect of the present invention there is provided a variable geometry turbine comprising:

- a turbine wheel supported in a housing for rotation about a turbine axis;
- an annular inlet passage defined between respective radial inlet surfaces of first and second wall members, at least one of said first and second wall members being moveable along the turbine axis to vary the size of the inlet passage;
- an array of vanes extending across the inlet passage, said vanes being connected to said first wall member;
- a complementary array of vane slots defined by the second wall member, said vane slots being configured to receive said vanes to accommodate relative movement between the first and second wall members;
- wherein the second wall member comprises a first plate defining a first array of openings so as to define said array of vane slots, said first plate comprising first and second segments defining respective first and second openings from said first array of openings, said first segment being displaceable relative to said second segment within a major plane of the first plate.

Preferably the first plate is annular in shape.

Each of said segments may comprise generally radially extending leading and trailing edges connected by radially inner and outer edges. A clearance may be defined between the leading edge of one segment and the trailing edge of a neighbouring segment. This clearance can then accommodate relative displacements between neighbouring segments.

Said radially inner and outer edges may possess different lengths. Preferably said radially inner edge may be shorter than said radially outer edge. Thus, it is preferred that each segment is flared from its radially inner edge to its radially outer edge.

Said leading and trailing edges may be swept forward relative to said radial line. The leading edge may be swept forward to a greater extent than the trailing edge.

At least one of said leading and trailing edges may be curved relative to a radial line passing through said segment and the turbine axis. Moreover at least one of said inner and outer edges of each segment may be curved.

It is thus preferred that each segment of the first plate has a scimitar-like cross-sectional shape as can be seen in the specific embodiments described below in relation to FIGS. **14**A, **14**B and **15**.

Both of said inner and outer edges of each segment may be curved, and said inner and outer edges may possess a substantially similar curvature.

The major plane of the first plate may be substantially orthogonal to the turbine axis.

The first plate comprised in the second wall member may be formed from any suitable material, such as stainless steel.

In a preferred embodiment of the third aspect, the second wall member comprises a second plate which is positioned axially adjacent to the first plate and said second plate being arranged co-axially or concentrically with respect to said first plate, the first plate defining a first array of openings which overlie a second array of openings defined by the second plate so as to define said array of vane slots.

In a preferred example of this embodiment the cross-sectional shape transverse to said turbine axis of at least one of the openings in said first array of openings may more closely match the cross-sectional shape transverse to said turbine axis of the vane that said at least one opening is arranged to receive than the cross-sectional shape transverse to said turbine axis of at least one of the openings in said second array of openings.

In this way, the openings in the second array of openings can be manufactured to a wider tolerance than those in the first array which are intended to closely match the cross-sectional shape of the vanes which the slots defined by the overlapping openings are intended to accommodate. As mentioned above in respect of other embodiments of the first and second aspects of the present invention, allowing one of the plates making up the second wall member to be manufactured to a wider tolerance reduces the cost and complexity of manufacturing this component.

Said at least one opening in said first array of openings may axially overlie said at least one opening in said second array of openings to define one slot of said array of vanes slots.

In a preferred version of the present embodiment, said second plate comprises first and second segments defining respective first and second openings from said second array of openings, said first segment of the second plate being displaceable relative to said second segment of the second plate within a major plane of the second plate.

Said second plate comprises first and second segments defining respective first and second openings from said second array of openings, said first segment of the second plate being displaceable relative to said second segment of the second plate within a major plane of the second plate.

Said first segment of the first plate may axially overlie said first segment of the second plate. Preferably overlying segments from the first and second plates are connected together such that rotational and/or radial displacement of a segment relative to the segment it overlies is prevented. Any suitable type of connection between overlying segments may be used, such as brazing.

In a similar fashion to the segments of the first plate, each of said segments of the second plate may comprise generally radially extending leading and trailing edges connected by radially inner and outer edges.

A further clearance may be defined between the leading edge of one segment and the trailing edge of a neighbouring segment. Said further clearance can accommodate relative displacement of segments of the second plate. Where overlying segments of the first and second plates are connected together so as to move in unison, it is preferable that the clearances defined between segments of the first plate and segments of the second plate are similar in shape so as to afford a similar degree of relative movement between segments in the first plate and segments in the second plate.

Said first segment of the second plate may be circumferentially offset with respect to said first segment of the first plate such that said clearance defined between segments of the first plate is circumferentially offset with respect to said further clearance defined between segments of the second plate. In this way the clearances defined between segments of the first plate do not axially overlie clearances defined between segments of the second plate so as to avoid presenting a leak path for gases flowing through the turbine inlet passageway.

The major plane of the second plate may be substantially orthogonal to the turbine axis.

In an additional embodiment of the first aspect of the present invention wherein at least the first plate is segmented, it is preferred that said first plate may be positioned axially closer to said first wall member than said second plate.

The periphery of the second plate may be received within a radially extending channel defined by the turbine housing. The second plate may possess a larger diameter than the first plate such that a region of the second plate may be located radially outwardly of the first plate, at least part of said region being retained within said channel by a retaining member. Said retaining member may be positioned axially closer to said first wall member than said second plate. Said retaining member may be fastened to the turbine housing.

The means of fastening may take any appropriate form, such as bolts, rivets and/or screws. Moreover any desirable number and/or arrangement of fasteners may be employed. By way of example only, it is envisaged that providing the retaining member with four equally angularly spaced apertures to receive suitable fasteners may be suitable.

The second plate comprised in the second wall member may be formed from any suitable material such as, stainless steel.

The array of vane slots may be provided as a substantially annular array of vane slots. The vane slots comprised in said annular array of vane slots may be substantially equi-angularly spaced.

One of said first and second wall members may be axially moveable and the other of said first and second may be fixed. Said fixed wall member may be defined by a facing wall of said housing.

According to a fourth aspect of the present invention there is provided a method for assembling a shroud plate for a variable geometry turbine, said shroud plate comprising at least two plates, the method comprising aligning a first of said plates with a second of said plates such that a first array of openings defined by the first plate overlies a second array of openings defined by the second plate so as to define an array of vane slots.

Preferably said at least two plates are concentrically aligned with respect to one another.

The shroud plate forming part of the fourth aspect of the present invention may be considered as the second wall member of the first aspect of the present invention. Moreover, in the preferred embodiments of the third aspect of the present invention employing at least two plates to form the second wall member, the method according to the fourth aspect of the present invention defined above is equally applicable.

Preferably the plates are concentric and/or may be arranged such that, when mounted within a turbine, they are co-axially aligned. Alignment of the first and second plates may comprise locating at least one projection such as a semi-shear or locating pin defined by one of said first and second plates within a complementary recess defined by the other of the first and second plates.

In a first preferred embodiment of the fourth aspect of the present invention, following alignment of the first and second plates, said plates are fixed together such that said first plate is substantially fixed rotationally and/or radially relative to said second plate. The plates may be fixed together by an adhesive, braze, rivet, screw, weld or the like. In another preferred embodiment, following alignment of the first and second plates, the plates are laminated together such that said first plate may be substantially fixed rotationally and/or radially relative to said second plate.

In a further preferred embodiment alignment of the first and second plates may comprise inserting first and second vanes connected to a variable geometry turbine nozzle ring into respective first and second vane slots from said array of vane slots. During and/or following insertion of said vanes into said vane slots, one of the plates may be rotated and/or radially displaced relative to the other of the plates to adjust the degree to which the first array of openings overlie the second array of openings so as to change the position of the first vane slot relative to the second vane slot. In this way, the relative orientation between slots can be optimised to suit a particular array of vanes connected to a turbine nozzle ring. Optimisation may be carried out prior to use of the turbine, in which case the first and second plates may be fixed together in the optimised configuration following adjustment. Alternatively, the plates may retain the ability to move relative to one another during use of the turbine so that optimisation is essentially carried out each time the array of vanes is inserted into the vane slots.

In a still further preferred embodiment said first plate may comprise first and second segments defining respective first and second openings from said first array of openings, said first segment being displaceable relative to said second segment within a major plane of the first plate, the method further comprising displacing said first segment relative to said second segment within the major plane of the first plate during and/or following insertion of said vanes into said vane slots to adjust the position of the first segment relative to the second segment so as to change the position of the first vane slot relative to the second vane slot. Segmenting the first plate forming part of the shroud plate enables the relative arrangement of vane slots to be optimised to match the arrangement of vanes on a turbine nozzle ring. As mentioned above in respect of the previous preferred embodiment, optimisation may be carried out before use of the turbine after which the segments of the first plate are fixed relative to one another, or the segments may remain displaceable throughout the lifetime of the turbine such that optimisation is carried out each time a vane is attached to a two line nozzle ring into the vane slots.

The or each plate which forms part of the shroud plate may be formed from any desirable material in any appropriate manner. For example, at least one of the plates may be formed by stamping from a rolled strip of stainless steel.

According to a fifth aspect of the present invention there is provided a method for preparing a shroud plate for use in a variable geometry turbine, said shroud plate comprising a first plate defining a first array of openings so as to define an array of vane slots, and said first plate comprising first and second segments defining respective first and second openings from said first array of openings, said first segment being displaceable relative to said second segment within a major plane of the first plate, wherein the method comprises inserting first and second vanes connected to a variable geometry turbine nozzle ring into respective first and second vane slots from said array of vane slots, and displacing said first segment relative to said second segment within the major plane of the first plate during and/or following insertion of said vanes into said vane slots so as to adjust the position of the first segment relative to the second segment such that the position of the first vane slot relative to the second vane slot more closely matches the position of the first vane relative to the second vane than before adjustment of the relative position of the first and second segments.

The fifth aspect of the present invention employs a segmented plate with a plurality of segments which can move relative to one another so as to permit optimisation of the relative displacement in relation to an array of vanes connected to a variable geometry turbine nozzle ring. As mentioned above in connection with previous aspects of the present invention, such optimisation can be carried out once before the turbine is used and the segments then fixed together in their optimised orientation or the segments can remain free to move relative to one another such that optimisation is essentially carried out each time the array of vanes is inserted into the vane slots defined by the shroud plate.

Other advantageous and preferred features of the invention will be apparent from the following description.

Specific embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

FIG. **1** is an axial cross-section through a known variable geometry turbocharger;

FIG. **2**A is a front view of a prior art shroud plate for use in a variable geometry turbine;

FIG. **2**B is a cross-sectional view taken along line G-G of the shroud plate of FIG. **2**A;

FIG. **3**A is a front view of a shroud plate according to a first embodiment of the present invention;

FIG. **3**B is a cross-sectional view of the shroud plate of FIG. **3**A;

FIG. **4**A is a front view of a front plate of the shroud plate of FIGS. **3**A and **3**B.

FIG. **4**B is a cross-sectional view of the front plate of FIG. **4**A;

FIG. **5**A is a front view of an intermediate plate of the shroud plate of FIGS. **3**A and **3**B;

FIG. **5**B is a cross-sectional view of the intermediate plate of FIG. **5**A;

FIG. **6**A is a front view of a back plate of the shroud plate of FIGS. **3**A and **3**B;

FIG. **6**B is a cross-sectional view of the back plate of FIG. **6**A;

FIG. **7** is a cross-sectional view of a shroud plate according to a second embodiment of the present invention;

FIG. **8**A is a cross-sectional view of an upper portion of the shroud plate of FIG. **7** supported within a turbine housing;

FIG. **8**B is a cross-sectional view of a lower portion of the shroud plate of FIG. **7** supported within the turbine housing;

FIG. **9** is a front view of a back plate of a shroud plate according to a third embodiment of the present invention;

FIG. **10** is a front view of a front plate to be used with the back plate of FIG. **9** to form the shroud plate according to a third embodiment of the present invention;

FIG. **11** is a cross-sectional view of the shroud plate according to the third embodiment of the present invention with the back plate of FIG. **9** attached to the front plate of FIG. **10**;

FIG. **12**A is a cross-sectional view of a turbine housing without a shroud plate or nozzle ring;

FIG. **12**B is a cross-sectional view of the turbine housing of FIG. **12**A with the shroud plate of FIG. **11** fastened to the turbine housing and a nozzle ring located axially adjacent to the shroud plate;

FIG. **13**A is a detailed cross-sectional view of the circled portion of the turbine housing of FIG. **12**A;

FIG. **13**B is a detailed cross-sectional view of the circled portion of FIG. **12**B showing the means of connection of the shroud plate of FIG. **11** to the turbine housing.

FIG. **14**A is a front view of a shroud plate according to a fourth embodiment of the present invention;

FIG. **14**B is a perspective view of the shroud plate of FIG. **14**A;

FIG. **15** is a front view of a segment of the shroud plate of FIG. **14**A;

FIG. **16**A is a cross-sectional view of an upper portion of a turbine housing with the shroud plate of FIG. **14**A attached to the housing;

FIG. **16**B is a cross-sectional view of the turbine housing and shroud plate of FIG. **16**A;

FIG. **17** is a detailed cross-sectional view of the circled region C of the turbine housing and shroud plate of FIG. **16**A;

FIG. **18**A is a cross-sectional view of a shroud plate according to a fifth embodiment of the present invention mounted within a turbine housing; and

FIG. **18**B is a perspective view of a section of a segmented annular plate forming part of the shroud plate FIG. **18**A.

Referring to FIG. **1**, this illustrates a known variable geometry turbocharger comprising a variable geometry turbine housing **1** and a compressor housing **2** interconnected by a central bearing housing **3**. A turbocharger shaft **4** extends from the turbine housing **1** to the compressor housing **2** through the bearing housing **3**. A turbine wheel **5** is mounted on one end of the shaft **4** for rotation within the turbine housing **1**, and a compressor wheel **6** is mounted on the other end of the shaft **4** for rotation within the compressor housing **2**. The shaft **4** rotates about turbocharger axis **4*a*** on bearing assemblies located in the bearing housing **3**.

The turbine housing **1** defines an inlet volute **7** to which gas from an internal combustion engine (not shown) is delivered. The exhaust gas flows from the inlet volute **7** to an axial outlet passageway **8** via an annular inlet passageway **9** and the turbine wheel **5**. The inlet passageway **9** is defined on one side by a face **10** of a radial wall of a moveable annular wall member **11**, commonly referred to as a "nozzle ring", and on the opposite side by an annular shroud **12** which forms the wall of the inlet passageway **9** facing the nozzle ring **11**. The shroud **12** covers the opening of an annular recess **13** in the turbine housing **1**.

The nozzle ring **11** supports an array of circumferentially and equally spaced inlet vanes **14** each of which extends across the inlet passageway **9**. The vanes **14** are orientated to deflect gas flowing through the inlet passageway **9** towards the direction of rotation of the turbine wheel **5**. When the nozzle ring **11** is proximate to the annular shroud **12**, the vanes **14** project through suitably configured slots in the shroud **12**, into the recess **13**.

The position of the nozzle ring **11** is controlled by an actuator assembly of the type disclosed in U.S. Pat. No. 5,868,552. An actuator (not shown) is operable to adjust the position of the nozzle ring **11** via an actuator output shaft (not shown), which is linked to a yoke **15**. The yoke **15** in turn engages axially extending actuating rods **16** that support the nozzle ring **11**. Accordingly, by appropriate control of the actuator (which may for instance be pneumatic or electric), the axial position of the rods **16** and thus of the nozzle ring **11** can be controlled. The speed of the turbine wheel **5** is dependent upon the velocity of the gas passing through the annular inlet passageway **9**. For a fixed rate of mass of gas flowing into the inlet passageway **9**, the gas velocity is a function of the width of the inlet passageway **9**, the width being adjustable by controlling the axial position of the nozzle ring **11**. FIG. **1** shows the annular inlet passageway **9** fully open. The inlet passageway **9** may be closed to a minimum by moving the face **10** of the nozzle ring **11** towards the shroud **12**.

The nozzle ring **11** has axially extending radially inner and outer annular flanges **17** and **18** that extend into an annular cavity **19** provided in the turbine housing **1**. Inner and outer sealing rings **20** and **21** are provided to seal the nozzle ring **11** with respect to inner and outer annular surfaces of the annular cavity **19** respectively, whilst allowing the nozzle ring **11** to slide within the annular cavity **19**. The inner sealing ring **20** is supported within an annular groove formed in the radially inner annular surface of the cavity **19** and bears against the inner annular flange **17** of the nozzle ring **11**. The outer sealing ring **20** is supported within an annular groove formed in the radially outer annular surface of the cavity **19** and bears against the outer annular flange **18** of the nozzle ring **11**.

Gas flowing from the inlet volute **7** to the outlet passageway **8** passes over the turbine wheel **5** and as a result torque is applied to the shaft **4** to drive the compressor wheel **6**. Rotation of the compressor wheel **6** within the compressor housing **2** pressurises ambient air present in an air inlet **22** and delivers the pressurised air to an air outlet volute **23** from which it is fed to an internal combustion engine (not shown).

Referring to FIGS. **2**A and **2**B, there is shown a prior art shroud plate for use in a variable geometry turbine. The shroud plate **24** is annular in shape and defines an annular array of vane slots **25** for receipt of vanes attached to a nozzle ring of a variable geometry turbine of the kind shown in FIG. **1**. The relative positioning of each vane slot **25** compared to the other vane slots **25** and the cross-sectional shape of each vane slot **25** should be very carefully controlled so as to ensure that each vane is correctly received within its respective vane slot **25** whilst also ensuring that disturbance to airflow passing over the vane slots **25** is minimised. The shroud plate **24** must therefore be manufactured to very high intolerances both in terms of the shape and position of each vane slot **25** to ensure proper functioning of the shroud plate **24** in combination with the nozzle ring (not shown). The shroud plate **24** defines a circumferential slot **26** which extends around the radially outermost edge of the shroud plate **24**. The slot **26** receives a ring (not shown) to support the shroud plate **24** within a turbine housing.

The shroud plate **24** is manufactured by turning from bar. Once a blank disc has been formed, the circumferential slot **26** is then cut into the radially outer edge of the disc. The vane slots **25** are then cut through the disc using, for example, laser cutting. Commonly, the vane slots **25** are cut sequentially, i.e. one at a time, making the manufacturing process relatively lengthy and expensive.

FIGS. **3**A and **3**B show a first embodiment of a shroud plate **27** in accordance with the present invention. The shroud plate **27** is again of generally annular form and defines an array of vane slots **28** to receive vanes connected to a nozzle ring of a variable geometry turbine of the kind depicted in FIG. **1**.

The shroud plate **27** is composed of three co-axial, concentric plates **29**, **30**, **31** which have been laminated together to prevent any rotational or radial movement of one of the plates relative to the other plates. The plates **29**, **30**, **31** may be laminated together in any suitable way, for example brazing. The centre plate **30** may be coated with a braze (e.g. by electroless nickel plating) on both radial faces and the two outer plates **29**, **31** then pressed into contact before placing the stacked plates **29**, **30**, **31** in a furnace, followed by appropriate cooling. In the embodiment shown in FIGS. **3**A and **3**B the plates **29**, **30**, **31** are arranged such that the plate **29** is the front (or outer) plate which will face an inlet volute of a variable geometry turbine and so it is this plate **29** which will be exposed to gas flowing from the inlet volute to an outlet passageway of the turbine. The plate which is intended to face the turbine housing is plate **31** which is commonly referred to as the back (or inner) plate. The back plate **31** defines three axially extending projections **32** which are received in complementary recesses **33** defined by the plate **30** which is positioned intermediate the front and back plates **29**, **31**. The projections **32** can be in the form of locating pins, semi-shears or any other suitable formation which would permit correct alignment of the back and intermediate plates **31**, **30**. Similarly, the intermediate plate **30** is also provided with a plurality of axially extending projections **34** which are received in complementary recesses **35** defined by the front plate **29**, thereby providing a means to ensure correct alignment of the intermediate plate **30** with respect to the front plate **29**.

Similar axially extending projections, such as semi-shears or pins, could be formed in the front plate **29**, projecting forwards, away from the centre and back plates **30**, **31**, such that they would project towards a nozzle ring during use. In this way, these projections could control the minimum inlet passage width of a turbine between the nozzle ring and shroud plate **27**. Such projections could supplement or replace pads which are often formed on the radial face of the nozzle ring for the same purpose, thereby reducing the cost and complexity of manufacturing the nozzle ring.

It can be seen from FIGS. **3**A and **3**B that the intermediate plate **30** possesses a smaller outer diameter than the front and back plates **29**, **31**. This is to provide the shroud plate **27** with a circumferential slot **36** extending around its radially outer edge for receipt of a ring (not shown) to support the shroud plate **27** within the turbine housing (not shown). It will be appreciated that circumferential slot **36** is provided to perform essentially the same function as circumferential slot **26** of the prior art shroud plate shown in FIGS. **2**A and **2**B. Each of the three plates **29**, **30**, **31** making up the shroud plate **27** of the present invention will now be described in more detail.

The front plate **29** shown in FIGS. **4**A and **4**B defines an annular array of openings **37** whose cross-sectional shape and relative annular positioning closely matches the shape and positioning of vanes of a nozzle ring (not shown) with which the shroud plate **27** will be used. That is, both the openings **37** and the vanes must be manufactured to a fine tolerance with respect to one another. In this way, the openings **37** can accommodate relative axial movement between the shroud plate **27** and the nozzle ring (not shown) but cause minimal disturbance to gas flowing through the inlet volute of the turbine.

The intermediate plate **30** is shown in FIGS. **5**A and **5**B. It can be observed in FIG. **5**A that the intermediate plate **30** defines an annular array of openings **38** whose relative annular position is similar to that of the openings **37** in the front plate **29**, however, the cross-sectional shape of each opening **38** takes a generally rectangular form with curved short sides **39** interconnecting long sides **40** of similar length to the length of each opening **37** in the front plate **29**. The general form of each opening **38** in the intermediate plate **30** is therefore easier to manufacture using more robust tooling than the openings **37** in the front plate **29**. The intermediate plate **30** can therefore be manufactured to wider tolerances at relatively low cost compared to the front plate **29**.

The back plate **31** is shown in FIGS. **6**A and **6**B, and defines a similar annular array of openings **41** to the array of openings **38** defined by the intermediate plate **30**. That is, the relative annular positioning of each opening **41** in the back plate **31** substantially matches that of the fine tolerance openings **37** defined by the front plate **29**, but the general form of each opening **41** in the back plate **31** is generally rectangular with curved short sides **42** connecting straight long sides **43** whose length approximates the length of the fine tolerance openings **37** in the front plate **29**. Consequently, the manufacturing tolerances required in respect of the back plate **31** are wider than those in the front plate **29**, making the back plate **31** easier and cheaper to manufacture.

FIG. **7** depicts a second embodiment of a laminated shroud plate. The shroud plate **44** shown in FIG. **7** is similar in structure to the shroud plate **27** of FIGS. **3**A to **6**B, however, the shroud plate **44** shown in FIG. **7** incorporates a series of locating pins **45**, **46** which project axially from the front plate **47** and intermediate plate **48** respectively to be received in complementary recesses **49**, **50** defined by the intermediate plate **48** and the back plate **51** respectively. The shroud plate **44** depicted in FIG. **7** includes fine tolerance openings **52** in the front plate **47** overlying wider tolerance openings **53**, **54** in the intermediate plate **48** and back plate **51** respectively. The openings **52**, **53**, **54** thus define vane slots **55** extending through the full width of the shroud plate **44**.

FIGS. **8**A and **8**B show how the shroud plate **44** depicted in FIG. **7** is supported within a turbine housing **56** during use. A circumferential slot **57** defined around the radially outer edge of the shroud plate **44** is dimensioned to receive a ring **58** which itself is dimensioned to be received within an annular channel **59** defined by the turbine housing **56**. In this way, the shroud plate **44** is securely supported within an axially extending clearance **60** defined by the turbine housing **56** in the correct orientation to receive vanes **61** attached to a nozzle ring (not shown) of a turbine. Axial movement of the nozzle ring causes the vanes **61** to be received through the vane slots **55** and extend into a suitably dimensioned clearance **62** defined by the turbine housing **56**.

Referring now to FIGS. **9**, **10** and **11** there is shown a third embodiment according to the present invention. In FIG. **9** a back plate **63** in the form of an annular ring defines an annular array of openings **64** which are positioned so as to overlie an annular array of openings **65** in a front plate **66** when the front plate **66** is connected to the back plate **63** to form an assembled shroud plate **67**, as shown in FIG. **11**.

The cross-sectional shape of the openings **64** defined in the back plate **63** more closely matches the cross-sectional shape of vanes attached to a nozzle ring (not shown) with which the assembled shroud plate **67** is intended to be used than the openings **65** defined by the front plate **66**. This embodiment therefore varies from the first two embodiments described above in relation to FIGS. **3**A to **8**B in that the two-piece shroud plate **67** according to the third embodiment positions the finer tolerance openings **64** in the back plate **63** and the wider tolerance openings **65** in the front plate **66** which will face gas flowing through the inlet volute of a turbine in which the shroud plate **67** is to be used.

As can be seen from FIGS. **9** to **11**, the back plate **63** defines a smaller outer diameter than the front plate **66** such that a radially outer region **68** of the front plate **66** extends radially beyond the periphery **69** of the back plate **63**. The extended region **68** of the front plate **66** defines four equally angularly spaced apertures **70** for receipt of fasteners, for example bolts, rivets or the like (not shown), to fasten the front plate **66** of the shroud plate **67** to the turbine housing as described in more detail below in relation to FIGS. **12**A to **13**B.

FIG. **12**A is a cross-sectional view of a turbine housing **71** prior to location of the shroud plate **67** from FIGS. **9** to **11** within the housing **71**. A more detailed view of the circled area A of FIG. **12**A is shown in FIG. **13**A. As can be seen from FIGS. **12**A and **13**A the turbine housing **71** defines an annular recess **72** for receipt of the front plate **66** of the shroud plate **67** and a further annular recess **73** lying rearwardly of the other recess **72**, the rear recess **73** being suitably dimensioned to receive the back plate **63** of the shroud plate **67**.

When it is desired to mount the shroud plate **67** within the turbine housing **71** the front and back plates **66**, **63** are inserted into their respective recesses **72**, **73** with the correct alignment to ensure that the wide tolerance openings **65** correctly overlie the fine tolerance openings **64** in the back plate **63** so as to define vane slots extending through the full thickness of the shroud plate **67** for receipt of vanes attached to a nozzle ring as shown in FIGS. **12**B and **13**B and as now described in more detail.

FIG. **12**B shows a cross-sectional view of a turbine housing with the shroud plate **67** in situ together with a nozzle ring **74** which has an annular array of axially extending vanes **75** attached thereto. Once the back plate **63** and front plate **66** have been received in the respective recesses **73**, **72** in the turbine housing **71**, and correctly aligned, bolts **76** or any other suitable fastener are inserted through apertures **70** defined by the front plate **66** into axially extending holes **77** defined by the turbine housing **71**. In this way, the front plate **66** is secured against the turbine housing **71** so as to substantially prevent any relative movement between the front plate **66** and the turbine housing **71**.

In contrast to the first and second embodiments of the present invention in which the three plates **29**, **30**, **31** making up the shroud plate **27** were laminated together so as to prevent any relative movement, the back plate **63** of the third embodiment is not fixed to the front plate **66**, such that the back plate **63** is permitted to rotate and/or displace radially relative to the front plate **66** even after having been mounted within the turbine housing **71**. This is to permit adjustment of the degree to which the fine tolerance openings **64** in the back plate **63** overlie the wider tolerance openings **65** in the front plate **66** which together define the vane slots. This in turn enables the alignment of a particular set of vane slots with a particular set of vanes **75** attached to the nozzle ring **74** to be accurately adjusted.

The shroud plate **67** according to the third embodiment of the present invention therefore provides a similar benefit in terms of allowing the shroud plate **67** to be formed from a plurality of discs wherein one set of openings is manufactured to a wider tolerance than the other set of openings (providing manufacturing and cost benefits as detailed above in respect of the first and second embodiments) but also the precise alignment of the back plate **63** and therefore the vane slots, can be adjusted after mounting the shroud plate **67** within the turbine housing **71**, such that fine manufacturing tolerances are only required in respect of the shape of the back plate **63** and the openings **64** rather than the position of the back plate **63** in the turbine housing **71**.

In the third embodiment described above, the back plate **63** lies entirely axially behind the front plate **66**, but it will be appreciated that it would be possible to modify the structure of the front and back plates **66**, **63** such that a part of the plate which can rotate and/or slide may be located nearer to the front of the shroud plate **67** which faces the gas flowing through the inlet volute **78** of the turbine housing **71**. In this way, at least some of the fine tolerance openings **64** could be exposed to the gas flowing through the inlet volute rather than the wide tolerance openings **65**, which would have the benefit of reducing disturbance to the gas flow.

The back plate **63** may be manufactured from any appropriate material, for example **304** stainless steel or the like. The front plate **66** may be manufactured from the same material as the back plate **63**, however, it may be advantageous to employ a material which better suits the thermal expansion of the material from which the turbine housing **71** is manufactured (typically iron) since the front plate **66** is bolted to the turbine housing **71**. Suitable materials (e.g. for use with an iron turbine housing **71**) include **420** stainless steel.

Referring now to FIGS. **14**A and **14**B, there is shown a fourth embodiment of a shroud plate **79** according to the present invention. The shroud plate **79** again defines an annular array of vane slots **80** defined by openings **81**, **82** in a front plate **83** and a back plate **84** respectively. In this embodiment the back plate **84** has a larger outer diameter than the front plate **83** such that a radially outer annular region **85** of the back plate **84** extends radially beyond the periphery **86** of the front plate **83** for reasons that will be explained below in relation to FIGS. **16**A to **17**.

The cross-sectional shape of the openings **81** in the front plate **83** more closely matches the cross-sectional shape of vanes of a nozzle ring (not shown) with which the shroud plate **79** is intended to be used than the openings **82** in the back plate **84**. In this way, the shroud plate **79** causes the minimum possible disturbance to gas flowing through an inlet volute of a turbine (not shown) in which the shroud plate **79** is to be used.

In this embodiment the front plate **83** and back plate **84** are each comprised of a plurality of discrete segments **88**, **89** respectively. Each segment **88** in the front plate **83** is secured (for example, by brazing) to its respective axially adjacent segment **89** in the back plate **84** such that each pair of axially adjacent segments **88**, **89** defines a pair of axially overlying openings **81**, **82** which combine to define an axially extending vane slot **80** as is depicted in FIG. **15**.

Each segment **88** of the front plate **83** has curved leading and trailing edges **90**, **91** which are connected by curved radially inner and outer edges **92**, **93**. Similarly, each segment **89** in the back plate **84** has curved leading and trailing edges **94**, **95** connected by curved radially inner and outer edges **96**, **97**. As can be seen from FIG. **15**, each segment **88** in the front plate **83** is circumferentially offset with respect to the corresponding segment **89** in the back plate **84**. In this way, the leading and trailing edges **90**, **91** of the front segment **88** are positioned further forward as compared to the leading and trailing edges **94**, **95** of the corresponding back segment **89**. Additionally, each front segment **88** is radially narrower than its corresponding back segment **89** such that the concave radially inner edge **96** of each back segment **89** lies radially inwardly of the concave radially inner edge **92** of each front segment **88**, and the convex radially outer edge **97** of each back segment **89** lies radially outwardly of the convex radially outer edge **93** of each front segment **88**. The concave leading edges **90**, **94** and convex trailing edges **91**, **95** of the front and back plates **88**, **89** extend generally radially outwardly. Each curved edge **90**, **91**, **94**, **95** is swept forward of a radial line X (see FIG. **14**A) passing through the centre of the shroud plate **79**.

The radially inner edges **92**, **96** and the radially outer edges **93**, **97** of the front and back segments **88**, **89** are also curved to an appropriate extent, taking into account the desired dimensions of the shroud plate **79** and the number of segments **88**, **89** forming the shroud plate **79**, which in this embodiment matches the number of vanes on the nozzle ring with which the shroud plate **79** is intended to be used. The leading edges **90**, **94** of each front and back segment **88**, **89** are swept forward to a greater extent than the trailing edges **91**, **95** such that each pair of segments **88**, **89** defines a scimitar-like cross-sectional shape in which the concave inner edge **92** of the front segment **88** is shorter than the convex radially outer edge **93** of the front segment **88**, and the concave radially inner edge **96** of the back segment **89** is shorter than the convex radially outer edge **97** of the back segment **89**.

The segments **88** forming the front plate **83** are circumferentially spaced from one another so as to define a small generally radially extending circumferential clearance **98**A between the leading edge **90** of one segment **88**A and the trailing edge **91** of a neighbouring segment **88**B. A corresponding generally radially extending clearance **98**B is defined between each pair of neighbouring segments **89**A, **89**B in the back plate **84**. It will be appreciated that the clearances **98**A, **98**B between each pair of neighbouring segments **88**, **89** in the front and back plates **83**, **84** might present a leak path for gas flowing through a turbine in which the shroud plate **79** is being used. In order to obviate this problem, each segment **88** in the front plate **83** is circumferentially offset compared to its axially adjacent back segment **89** as can clearly be seen in FIG. **15**. In this way, the clearances **98**A, **98**B in the front and back plates **83**, **84** do not axially overlie. Rather, the clearance **98**A between each pair of segments **88**A, **88**B in the front plate **83** is closed by a region of each back segment **89** which lies axially behind the trailing edge **91** of each front segment **88**. The clearances **98**A, **98**B in the front and back plates **83**, **84** permit radial and rotational displacement of one segment pair **88**A,**89**A relative to its neighbouring segment pair **88**B, **89**B. In this way, each segment pair **88**A, **89**A can adopt precisely the correct position to receive a vane (not shown) attached to a nozzle ring (not shown) during use.

Referring now to FIGS. **16**A, **16**B and **17**, the shroud plate **79** according to the fourth embodiment of the present invention is mounted within a turbine housing **100** by receipt of the back plate **84** in an annular recess **101** defined by the turbine housing **100** with the front plate **83** being received in a further annular recess **102** defined by the turbine housing **100**. Once the front and back plates **83**, **84** of the shroud plate **79** have been received in their respective recesses **102**, **101**, a retaining ring **103** is located towards the radially outer periphery of the shroud plate **79** in its own annular recess **104**. As can be seen most clearly in FIG. **17**, the ring **103** extends radially inwardly so as to axially overlie the region **85** of the back plate **84** which extends radially outwardly of the front plate **83**. In this way, the ring **103** can be used to retain the back plate **84** against the turbine housing **100** and thereby retain the front plate **83** in place by virtue of each segment **88** in the front plate **83** being secured to its respective axially adjacent segment **89** in the back plate **84**. The ring **103** defines apertures **105** for receipt of suitable fasteners **106**, such as bolts, rivets or the like, which are received in axially extending holes **107** defined by the turbine housing **100**.

After mounting the shroud plate **79** within the turbine housing **100** a nozzle ring **108** carrying a plurality of axially extending vanes **109** is then displaced axially towards the shroud plate **79** such that each vane **109** is inserted into its respective vane slot **80** defined by the overlying pairs of openings **81**, **82** in the front and back plates **83**, **84**. In view of the segmentation of the front and back plates **83**, **84** and the clearances **98**A, **98**B defined between each segment pair **88**, **89**, the segment pairs **88**, **89** can displace radially and rotationally relative to one another so as to afford the optimum alignment of each segment pair **88**, **89** with respect to its corresponding vane **109**. In this way, the back plate **84** can be manufactured more simply and at lower cost since it needs only to define relatively wide tolerance openings **82**. Additionally, since each opening **81** in the front plate **83** needs to be manufactured to a fine tolerance only in terms of its cross-sectional shape, rather than its position relative to the other openings **81**, this allows the relative orientation of the vanes on the nozzle ring to be manufactured to a wider tolerance thereby simplifying production and reducing cost.

The front and back plates **83**, **84** of the shroud plate **79** can be manufactured from any appropriate material, such as stainless steel. It may be advantageous to select a material for at least the back plate **84**, if not also the front plate **83**, which suits the thermal expansion of the turbine housing **100** during use. Suitable materials include **304** stainless steel for the front plate **83** and **420** stainless steel for the back plate **84**.

While the shroud plate **79** may permit relative rotational and/or radial movement between pairs of axially adjacent segments **88**, **89** in the front and back plates **83**, **84** throughout operation of a turbine incorporating the shroud plate **79**, the optimum positioning of each segment pair **88**, **89** may be determined prior to use by insertion of the nozzle ring vanes **109** into the vane slots **80**, adjustment of the segments **88**, **89** to their mutually optimum positions followed by fixation of each segment pair **88**, **89** relative to the other segment pairs, for example by brazing. In this way, the shroud plate **79** would be optimised for a particular nozzle ring **108** prior to use and then fixed in this optimum configuration for future use.

FIGS. **18**A and **18**B show a fifth embodiment of a shroud plate **110** according to a fifth embodiment. The shroud plate **110** comprises three coaxial, concentric plates consisting of a rear plate **111**, an intermediate segmented plate **112** and a front plate **113**. As can be seen from FIG. **18**A, the intermediate plate **112** defines relatively fine tolerance openings **114** which axially overlie larger openings **115**, **116** in the rear and front plates **111**, **113** respectively so as to define vane slots **117** for receipt of vanes in a vane cavity **118** in the same way as the first four embodiments described above.

In the fifth embodiment, the intermediate segmented plate **112** is made up of an annular array of segments **112***a* of generally similar form to the segments described above in relation to the fourth embodiment. Each segment **112***a* of the intermediate plate **112** is supported between the front and rear plates **113**, **111** so as to be radially and rotationally displaceable with respect to its neighbouring segments **112***b*, **112***c*. In this way, each segment **112***a* can adopt the optimum configuration to receive its respective vane. In the fifth embodiment, the segmented intermediate plate **112** defines a smaller outer diameter than the rear plate **111**, which itself defines a smaller outer diameter than the front plate **113**. The radially outer periphery of the front plate **113** thus extends radially outwardly compared to both the intermediate plate **112** and the rear plate **111**. The front plate **113** defines a radially extended portion **119** which defines a tapered aperture **120** for receipt of a countersunk retaining bolt **121**. The retaining bolt **121** defines a shaft **122** which is of narrower cross-section than the counter bore **123** which receives the shaft **122** of the bolt **121**. In this way, a clearance is defined between the shaft of the bolt **122** and the bore **123** to accommodate thermal expansion flexing of these components.

It can be seen that radial clearances **124**, **125** are defined radially outwardly of the intermediate plate **112** and radially inwardly of the plate **112** respectively. Moreover, even though the rear plate **111** defines a larger outer diameter than the intermediate plate **112**, the rear plate **111** extends radially inwardly to the same extent as the intermediate plate **112** such that the clearance **125** defined between the turbine housing **126** and the radially inner periphery of the intermediate plate **112** is of constant radial dimension and extends axially beyond the radially inner edge of the rear plate **111** towards the turbine housing **126**.

As shown in FIG. **18**B not only are radial clearances **124**, **125** defined beyond the radially outer and inner edges of the intermediate plate **112**, but generally radially extending clearances **127** are also defined between each pair of adjacent segments **112***a*, **112***b* and **112***a*, **112***c* to afford sufficient clearance to accommodate radial and/or rotation movement between the segments **112***a* making up the intermediate plate **112**.

It will be appreciated that the number of plates used in each of the shroud plates representing different embodiments of the present invention described above can be varied from the number described in respect of each embodiment. For example, the first and second embodiments in which each plate is fixed to it neighbouring plates are not limited to using three plates. Rather, two, four, five or more annular plates may be employed defining annular arrays of openings overlying one another so as to define appropriately dimensioned and positioned vane slots. Moreover, the means by which the shroud plates of the first and second embodiments are supported within a turbine housing is not limited to the use of an annular ring extending around the circumference of the shroud plate. The front plate or plates may have a larger outer diameter than one or more of the back plates, in a similar fashion to the third embodiment described above, such that the front plate or plates could be fastened to the turbine housing. Alternatively one or more of the back plates could possess a larger outer diameter than one or more of the front plates, in a similar fashion to the fourth embodiment, in which case an annular ring or other suitable fastener, such as a bolt, rivet or the like may be used to secure the back plate(s) to the turbine housing to hold the shroud plate in place.

Similarly, the shroud plates according to the third and fourth embodiments described above may incorporate any desirable number of annular plates and are not limited to using just two plates as described above in respect of the specific embodiments. For example, the third and/or fourth embodiments may incorporate three, four or more annular plates with annular arrays of openings which overlie one another so as to define appropriately dimensioned and positioned vane slots.

The cross-sectional shape and relative spacing of the vane slots defined by the shroud plates of each embodiment may take any convenient form and is not limited to the exact form depicted in FIGS. **3**A to **18**B. Moreover, while it is desirable that the fine tolerance openings have a cross-sectional shape which is very similar to the cross-sectional shape of the vanes connected to the nozzle ring with which the shroud plate is to be used, it will be appreciated that the size and shape of the wider tolerance openings may be varied from that shown in FIGS. **3**A to **18**B to suit a particular application and/or to reduce the cost and complexity of the manufacturing process.

The invention claimed is:

1. A variable geometry turbine comprising;

a turbine wheel supported in a housing for rotation about a turbine axis;

an annular inlet passage defined between respective radial inlet surfaces of first and second wall members, at least one of said first and second wall members being moveable along the turbine axis to vary the size of the inlet passage;

an array of vanes extending across the inlet passage, said vanes being connected to said first wall member;

a complementary array of vane slots defined by the second wall member, said vane slots being configured to receive said vanes to accommodate relative movement between the first and second wall members;

wherein the second wall member comprises a first plate defining a first array of openings so as to define said array of vane slots, said first plate comprising first and second segments defining respective first and second openings from said first array of openings, said first segment being displaceable relative to said second segment within a major plane of the first plate; and

wherein the second wall member comprises a second plate and a third plate, each of the second and third plates being positioned axially adjacent to the first plate and being arranged co-axially with respect to said first plate, the second and third plates being disposed on opposite sides of the first plate such that the first plate forms an intermediate plate of the second wall member, wherein the second plate defines a second array of openings and the third plate defines a third array of openings, the second and third arrays of openings both overlying the first array of openings so as to define said array of vane slots.

2. A variable geometry turbine according to claim **1**, wherein each of said segments comprises generally radially extending leading and trailing edges connected by radially inner and outer edges.

3. A variable geometry turbine according to claim **2**, wherein at least one of said leading and trailing edges is curved relative to a radial line passing through said segment and the turbine axis.

4. A variable geometry turbine according to claim **1**, wherein the second wall member comprises a second plate which is positioned axially adjacent to the first plate and said second plate being arranged co-axially with respect to said first plate, wherein the first array of openings overlies a second array of openings defined by the second plate so as to define said array of vane slots.

5. A variable geometry turbine according to claim **1**, wherein the cross-sectional shape transverse to said turbine axis of at least one of the openings in said first array of openings more closely matches the cross-sectional shape transverse to said turbine axis of the vane that said at least one opening is arranged to receive than the cross-sectional shape transverse to said turbine axis of at least one of the openings in said second array of openings and at least one of the openings in said third array of openings.

6. A variable geometry turbine according to claim **1**, wherein each of the first and second segments of the first plate is supported between the second and third plates so as to be radially and rotationally displaceable with respect to its adjacent segments.

7. A variable geometry turbine according to claim **1**, wherein a radial clearance is defined radially outwardly of the first plate, between the first plate and the housing.

8. A variable geometry turbine according to claim **1**, wherein a radial clearance is defined radially inwardly of the first plate, between the first plate and the housing.

9. A variable geometry turbine according to claim **1**, wherein a generally radially extending clearance is defined between the first and second segments to afford sufficient clearance to accommodate relative radial and/or rotation movement of the first and second segments.

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